NEW MATERIALS AND PROCESSES IN THE FIELD OF ENGINEERING.

Paper presented to the Institution—London, Leicester, Luton, Edinburgh, Birmingham, Glasgow, Southern, Preston, Eastern, and Western Sections, by L. W. Johnson, M.Met., M.I.P.E.

WHEN one considers that there are available some 74 elements of which say 25 are in common use and that since it is the fashion nowadays to develop not binary alloys but quite complicated mixtures, you will realise that the possible number of combinations will reach astronomical figures. In any case the number of actual alloys and materials in use at the present time must run into thousands, and consequently I was not a little worried as how best to tackle this paper. I am going to attempt to touch lightly upon as many new materials and processes as possible, but am afraid that there are many which because of space and time must be omitted. Also, whilst I have endeavoured to confine processes to a group in themselves, occasionally it has not been possible to prevent incorporating them with materials.

I propose to commence with precipitation hardening alloys since, although this form of heat treatment was first brought to the fore in pre-war days by Wilm in connection with duralumin, and apart from the introduction of the RR series of aluminium alloys some six or seven years ago it is only recently that considerable attention has been paid to the possibilities of improving mechanical properties by this means.

Precipitation Hardening.*

This subject is known under a number of names, i.e., " precipitation hardening," " dispersion hardening," and " age hardening "

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* For fuller details see *Precipitation Hardening; Its Scope and Possibilities*, by P. D. Merica, Metal Progress, 1935. Vol. XXVII, January, pp. 31-35 and 60; March, pp.46-50 and 74; June, pp. 29-32; July, pp. 41-45.

—all of which are currently used and reflect to some extent the form the hardening takes. In order, however, to describe this phenomenon briefly, it will be best to choose a simple example such as silver-copper alloy corresponding approximately to sterling silver.

Metallic silver dissolves 8.8% of copper in solid solution at 780°C. (1435°F.); the copper solubility diminishes, however, with decreasing temperature, dropping to perhaps 2% at 300°C. (600°F.) and below. When an 8% copper-silver alloy is slowly cooled from 750°C., copper is therefore continuously precipitated from solid solution, leaving at 300° about 2% still in solid solution and 6% in the form of precipitated free copper. The alloy after this treatment is moderately harder than pure silver.

Precipitation of the excess copper may, however, be prevented by cooling fairly rapidly from 750°C., after which treatment the copper is retained in supersaturated solution at ordinary temperatures. In this condition the alloy is still soft, softer, indeed, than in the slowly cooled condition. This supersaturated solution of copper in silver is unstable in the sense that it will precipitate excess copper if tempered for a few hours at about 300°C. Because of limited diffusion velocity at these temperatures, the copper is precipitated, not in relatively coarse particles as during slow cooling but as a shower of finely dispersed particles of submicroscopic size. The alloy after such treatment is considerably harder than after slow cooling or after quenching. Actual Brinell hardness values are about as follows :—

As slowly cooled	70
As quenched	55
Quenched and aged at 300°C. ...	110
Quenched and aged at 500°C. ...	75

The last line shows that if the tempering treatment is executed at higher than the optimum temperature, the precipitated copper particles coalesce somewhat, their size is greater, their number less, and the resulting "age-hardness" also less, i.e., the alloy "over-ages."

Precipitation hardening is found only in alloys and not in pure metals, since segregation of a second metal or constituent is required. The standard heat treatment which induces it comprises (1) annealing at a high temperature long enough to bring about solution of the hardening constituent; i.e., a "solution treatment," (2) rapid cooling or quenching to ordinary temperatures to suppress the normal coarse precipitation, and (3) "ageing" either at room temperature or a low temperature "tempering," to produce the finely dispersed precipitate. It is found only in those alloys in which supersaturated solid solutions are possible; in consequence, only

in alloys in which there occur fairly marked changes of solubility of some alloy constituent, as the temperature changes.

One of the most striking examples is beryllium bronze, containing about 2.5% of beryllium. This material, which is readily rolled either when hot or cold, is fairly soft and ductile when annealed, with a tensile strength of 24 tons per square inch and an elongation of 55%. When quenched and aged it is very substantially hardened and strengthened and has tensile strengths over 67 tons per square inch, together with elastic limits of over 36 tons per square inch. When cold worked and aged, the properties are still higher. Ductility after such treatments, as evidenced by an elongation of about 1.5%, is unfortunately low, but it is entirely adequate for many purposes, and in particular for that for which the material is principally used, namely, for springs.

Incidentally, beryllium works not only in copper but in nickel, in iron, and in austentitic steels as well. The metal is however somewhat expensive, but at the same time is an efficient hardener.

Copper lends itself readily to precipitation hardening. When alloyed with about 2.5% beryllium it can be heat treated to about 400 Brinell. This is a very respectable hardness for 97% copper, when it is considered that copper, even when cold worked, does not yield a hardness much above 100 Brinell. Indeed, in this alloy possibly culminates the old, old search for hardened copper.

Even the soft white metals can be improved. A 2.5% antimony-lead alloy can be heat treated to about 5 tons per square inch tensile strength ; with as little as 0.1% calcium the strength of lead can be boosted, by adequate ageing, to about 3½ tons per square inch. These figures compared vey favourably with that of about 0.9 tons per square inch, which represents the short time tensile strength of lead itself.

Gold-copper alloys hardened by platinum or palladium will develop tensile strengths in the neighbourhood of 67 tons per square inch through suitable heat treatment alone and without cold working. These are rather noteworthy values when compared with the normal strengths of the constituent metals, of which the highest is about 15 tons per square inch for copper.

In tables 1, 2, 3, 4, and 5 particulars are given of the effect of precipitation hardening on various alloys which have been recently developed. It will be noted that by interposing a certain amount of cold work between the two heat treatments the tensile strength can be still further improved. The advantages of working the alloy in the soft condition and subsequently hardening the finished product by a simple slow temperature reheating operation will be obvious from a production point of view.

In tables 1 and 2, which relate to "Kunial" copper and "Kunial" brass respectively the essential hardening agents are nickel and

aluminium. Obviously in those alloys already containing nickel it is only necessary, in order to obtain precipitation hardening, to add aluminium. Silicon will also act in a manner similar to aluminium. As will be seen from table 1 there is an optimum reheating temperature, for producing the best combination of properties, i.e., in the case of " Kunial " copper this lies between 500 and 600°C. Tables 6 and 7 give the physical properties and mechanical properties at elevated temperatures respectively of K Monel which is the precipitation hardening form of Monel Metal.

The advantage of precipitation hardening as opposed to cold work in improving the strength of a metal will be appreciated from Fig. 1 in which it will be seen that a machining operation will at once remove most of the effects of cold work.

Steels : Nitriding.

The original nitriding steels, containing aluminium as one of the essential elements for producing a very hard skin when subjected to the action of ammonia at a temperature of 500°C, had diamond hardness number of the case of the order of 1,000 or more. While such a hardness value has been beneficial especially for those applications where it is difficult to maintain adequate lubrication, there has been in recent times a distinct demand for an intermediate type of steel which would acquire by nitriding a skin of somewhat lower hardness than chromium-aluminium steels, so as to give a greater degree of toughness of the skin and less liability to flaking. This has been achieved in various ways, in one of which aluminium is omitted and chromium-molybdenum steels are used to which has been added either nickel or vanadium. Typical compositions are as follows :—

		Ni.	Cr.	Mo.	V.
Firth-Brown	HCM ...	0.5	3	0.4	—
	GK ...	—	2	0.2	0.15
	CM ...	0.6	1	1.2	—

The surface hardness obtained from the above types of steel respectively are as follows :—

800/850
750/800
600/650

For any of these three types the carbon content may be varied according to the tensile strength required in the finished article. Usually three grades of carbon are employed, approximately of the order of 0.2, 0.3, and 0.4%. The most important applications are respectively for cylinders, embossed printing rollers, and crankshafts.

French and Homerberg* have described a steel containing 0.5% each of chromium, aluminium, molybdenum, and vanadium, together with 2.5% of nickel, which on nitriding produces a case of about 1,000 hardness but which has increased toughness. Improvements are also effected at the same time in the core by the development of dispersion hardening.

Nitriding has also been extended to cast iron of a suitable composition and it is possible to obtain a hardness of over 900. The main use of nitrogen hardened cast iron is for cylinder liners owing to the greater increased resistance to wear which is obtained.

Corrosion- and Heat-Resisting Steels.

Whilst stainless steels were not discovered in the period under review, yet the last two or three years have seen exceptional development in the applications. This especially applies to the austenitic type of nickel-chromium stainless steel, which is sometimes known as the 18/8 type. At one time a certain amount of trouble was experienced in the after effects of the welding of these steels but this problem has now been successfully tackled and there are now available on the market steels quite resistant to this particular trouble. For instance, in the case of "Staybrite," the special variety of this steel known as F.D.P. contains just under 1% each of tungsten and titanium.

A great deal of attention has been drawn recently to the Budd shot welding process which originated in the U.S.A. This process is a mechanised form of spot welding in which the duration of the time and temperature of the weld is very accurately controlled, so that is is claimed that even with steel which is subject to weld decay, welds made of this process are immune. The process certainly has much to recommend it, but may be pointed out that since the development of the weld decay proof type of steel, such as that mentioned above, ordinary standard types of spot welding machines can be used without any danger.

Whilst it is not a steel, mention may be made in this section of a new material known as "Inconel," which has recently been developed for corrosion and heat resisting purposes. It contains approximately 80, 14, and 6% respectively of nickel, chromium, and iron. The mechanical properties and physical constants of "Inconel" are given in tables 8 and 9.

Magnet Steels.

Mishima, about 1930, discovered in Japan the remarkable M.K. nickel-aluminium magnet steel which contains generally :—

**Trans. Am. Soc. Steel Treating, Vol. XX. Dec. 1933. No. 6.*

Nickel	...	25%
Aluminium	...	12%

Its outstanding characteristic is the high coercive force as compared with even the 36% cobalt magnet steel. Also the heat treatment required is much simpler. The steel is unworkable and unmachinable and has, therefore, to be cast to shape and finally ground.

Honda more recently has obtained even better results with an alloy containing :—

Cobalt	...	15-20%
Nickel	...	10-25%
Titanium	...	8-25%

Aluminium may be present in small amounts.

Cast Iron.

Comparatively recent developments in the cast iron field relate to corrosion and heat resistance and to the production of specially strong irons.

Two types of iron known as " Ni-Resist " and " Nicrosilal " are now available for corrosion and heat resistance respectively, and typical chemical compositions are as follows :—

		Ni-Resist	Nicrosilal
Total carbon	...	3.0	1.8
Silicon ...	...	1.5	6.0
Manganese	...	1.0	1.0
Nickel ...	...	14.0	18.0
Copper ...	...	7.0	—
Chromium	...	2.0	2.0

" Ni-Resist " possesses a marked degree of corrosion as well as heat resistance, especially with reference to attack by weak sulphuric acid, is non-magnetic, and also has a co-efficient of expansion similar to that of " Lo-Ex " aluminium alloy.

Nicrosilal was developed essentially for heat resistance and in the composition given above is recommended for use up to 750°C. By increasing the chromium up to 5%, improved resistance is obtained up to say 850°C. The increase in chromium, however, reduces the machinability somewhat.

Cast iron produced by ordinary foundry methods rarely gives strengths in excess of 20 tons per sq. in. It is, however, possible to obtain figures as high as 30 by preparing in the bath an iron which would cast white under normal conditions and subsequently " inoculating " or graphitising the metal by the addition of suitable proportions of nickel and silicon. Such an iron is known as " Ni-Tensyl."

Interest has also been taken in the manufacture of automobile cast crankshafts in order to obviate the difficulty sometimes experienced in machining the balance weights of forged shafts. The Ford Motor Co.* have developed a material which falls between cast iron and cast steel. The composition is :—

C.	...	1.35 to 1.6%
Si.	...	0.35 to 1.1%
Mn.	...	0.6 to 0.8%
Cu.	...	1.5 to 2.0%
Cr.	...	0.4 to 0.5%
S.	...	0.06 max. %
P.	...	0.1 max. %

The heat tretment consists of holding for twenty minutes at 1650°F. (900°C.) and air quenching to a minimum of 1200°F.(650°C.), followed by reheating to 1480°F. (805°C.). After holding for one hour the crankshaft is cooled in the furnace to 1000°F. (540°C.) during a further hour.

The following properties are obtained :—

Elastic limit, tons to sq. in.	40.6
Maximum stress, tons to sq. in. ...	48.2
Elongation %	3
Brinell hardness number	269

Impact : 50 ft. weight falling 40 in. on to the flange at the centre of the main bearing while supported on the two end main bearings.

Copper.

Distinct progress has been made in the welding of copper. For many years it was not possible to obtain satisfactory welds in copper owing to the fact that the copper oxide, which is always present in the tough pitch kind of copper reacted with the hydrogen in the flame with the consequent production of gas and blow holes. It has now been overcome by using a deoxidised copper, both for the copper to be welded and for the copper welding rod. The welding is most suitably carried out by the oxy-acetylene process. The metallic arc process has not been found to be very satisfactory owing to the high electric and heat conductivity of the copper which produced spluttering of the arc and high dissipation of heat. This can partly be overcome by using a bronze welding rod but the resultant weld will, of course, not have such a good conductivity.

**Metals and Alloys, October, 1935, p. 259.*

Bearing Alloys.

Copper-lead has come into prominence in connection with bearings and more especially in internal combustion engines. In developing the high speed diesel engine it was found that the standard type of white metal would not in general stand up in the big ends to the pounding due to the higher loads and this trouble was finally overcome by adopting a steel backed copper-lead bearing, the composition varying somewhat but may be about 70/30 copper-lead. The main difficulty is to ensure an even mixing of the copper and the lead and the prevention of segregation. Whilst various methods have been adopted some of the most satisfactory employ a centrifugal casting process and for those who are interested in details attention is drawn to an article appearing in *Machinery* Vol. 46, No. 1194. 29/8/35, p. 653, which described the methods adopted at the A.E.C. The particular composition in this case being 74% Cu., 1% tin and lead reainmder. *

A further process, which is used in the production of copper lead alloy, steel bushes involves passing mild steel strip about $^1/_{16}$ in. thick through a bath of the molten copper-lead alloy at 1150°C and subsequently through a graphite die to wipe off excess metal and secure a smooth surface. The coated strip is then subjected to various finishing operations and formed into semicircular half bushes.

It may be of interest to point out that in America the Bohn Aluminium Corporation are stated to be turning out 10,000 a day of copper-lead bearings for automobile use.

Bearings Moulded From Copper Powder Mixtures.

Advances in the technique of moulding metallic powders permit the production of bearing bushes for medium loads with the minimum of manufacturing operations and with consequent saving in cost. With controlled manufacturing conditions, the moulded bushes possess good mechanical properties, although they will not withstand very severe loading.

A typical mixture consists of 93% copper powder with 7% tin powder, and graphite is also sometimes added. The powder used for moulding is sharp grained and is graded to give direct control of grain size, while freedom from inter-crystalline oxide is also ensured.

The powders are moulded in self-ejecting presses under pressures of 5,000 lb. per sq. in. and upwards, the pellets afterwards being sintered, that is furnace heated, in a reducing atmosphere at a temperature below the melting point of the constituents.

**See also Irson Age, August 8, 1935.*

By controlling the moulding pressures it is possible to produce bearings having a density from 75% upwards of the equivalent solid metal density and the bearings can thus be made slightly porous to hold oil if necessary. This property of self-lubrication has been exploited for bearings difficult to lubricate on automobiles, such as brake camshaft bushes. Porous moulded bronze bushes are also used in machinery for textile and other trades where oil splashing is objectionable.

The moulded dimensions may be controlled to within limits of 0.001 in., but a final sizing operation is usually given by drifting. As the satisfactory performance of moulded bearings is usually to a large extent associated with the openness of the structure, it is important that machining or grinding operations, which would partly ruin this feature, should be avoided.

Moulded bearings should be inserted into their housings with a special supporting mandrel so as to preserve accurately the size and conditions of the bearing and hence avoid necessity for further machining or fitting. For automobile work the recommended housing fits for these bearings have been standardised under Institution of Automobiles Engineers Data Sheet Number 186.

Cadmium-Nickel Bearing Metal.

Recently considerable attention has been paid to the possibilities of cadmium as a bearing metal since the publication of a paper by Swartz and Phillips " A Comparison of Certain White Metal Bearing Alloys particularly at Elevated Temperatures " which was published by The American Society for Testing Metals, 1933, vol. 33, part 2, p. 416. The authors experimented with two alloys which contained respectively 1.35 and 3% of nickel, and in comparing with standard white metal found that the cadmium-nickel alloy possessed superior properties at elevated temperatures, e.g., higher softening, higher order of creep resistance and also greater hardness, combined with ductility equivalent to that of white metal. The use of such bearing metal is not at present widespread but there are indications that in the near future it will be much more widely adopted. The alloy bonds satisfactorily to steel.

Lead.

One of the drawbacks to the use of lead, especially for the purposes of sheathing, is its very low fatigue value combined with its high density which has in the past resulted in a large number of failures. Work has been directed to improving the fatigue value of lead and by the use of about $\frac{1}{4}$% of cadmium together with $1\frac{1}{2}$% of tin or $\frac{1}{2}$% of antimony the fatigue value can be increased as much as four to five times. The improvement of three or four times can also

be achieved by the addition only of 0.05% of tellurium which also considerably increases the ductility under prolonged stress and has been found beneficial in the case of preventing bursting due to frost.

Aluminium Alloys.

The saving in weight which can be effected by the use of aluminium alloys has been reflected in their increasing adoption in those industries connected with transportation. Amongst the wrought alloys Duralumin and R.R.56 are now well established owing to their high strength weight ratio. For those applications where corrosion resistance is of importance for instance to salt spray, attention has been paid to the beneficial effect resulting from the addition of up to 7% of magnesium to aluminium e.g., Birmabright, Mg7, and R.R.66. These alloys possess a range of tensile strength from about 15 to 27 tons per sq. in. according to the amount of cold work imparted. They are not susceptible to precipitation hardening in the same way as Duralumin or R.R.56.

Reference may be made also to the more extended use of modified forms of high silicon alloys such as " Lo Ex " which because of its low co-efficnent of expansion has found increasing application for automobile pistons. The composition of this alloy is approximately :

Silicon	14.0%
Copper	0.8%
Nickel	2.0%
Magnesium	1.0%

The actual co-efficient of expansion of this material is 0.000019 per °C. as compared with the value of about 0.0000224 for ordinary aluminium alloys. It will be appreciated that as the co-efficient of expansion of " Lo-Ex " is thus much nearer than that of the ordinary aluminium alloys to that of cast iron, which is used for cylinders and cylinder liners, a much closer fitting piston can be used.

In connection with processes, attention may be drawn to the anodic oxidation process which was orginated several years ago by Dr. Bengough and consists of making the aluminium the anode in a chromic acid bath which results in the production of a hard adherent oxide film possessing very good resistance to corrosion. Dr. Bengough subsequently pointed out that this oxide film could be dyed. More recent development of this anodic process have consisted in modifying the actual solution used whereby sulphuric acid is substituted for chromic acid and also other addition agents are present. This has resulted in a process which has not the same danger for workers as is the case with chromic acid and it is also claimed that the anodic oxide film is somewhat easier to dye. In any case very pleasing effects can be obtained with aluminium coloured in this way.

There is also the modified Bauer-Vogel Process usually known as M.B.V., in which the articles are immersed in a solution containing 5% Na_2Co_3, 1.5% sodium chromate at a temperature of 90° to 100°C. for five to ten minutes during which the surface is covered with a protective film. The protection, whilst being very good, is inferior to that obtained by anodic treatment.

Magnesium Alloys.

Since magnesium alloys represent a saving in weight of about 40% as compared with aluminium alloys it is not surprising that they are receiving attention, more especially in those industries where saving of weight is important. Recent development are more connected with the production of casting alloys which can now be heat-treated with an increase of maximum stress from about 9 to 13 tons per sq. in. While magnesium alloys have fairly good resistance to atmospheric corrosion they are very susceptible to marine conditions and various methods have been adopted to protect them from such conditions. Reference may be made to the work of Drs. Sutton and Bengough who have developed solutions in which the magnesium parts are dipped. Sutton* uses a potassium chromate-sodium sulphate solution, the immersion being for six hours at 95°C.

Bengough† uses a 10% selenious acid solution with 0.1/0.5% sodium chloride at room temperature and immerses for five to ten minutes.

Wear Resistance.

Recent developments in this particular field have been in the use of stellite as a protective layer which is applied in the manner of welding by a suitable flame. As stellite retains its high hardness after being heated to high temperatures it is not only used for wear resistance at room temperatures but also for protecting exhaust valve seats and the like.

A special alloy cast iron known as Ni-hard has also been developed for wear resistance which possesses a Brinell hardness of from 700 to 800.

Cladding.

We are all familiar with the old process whereby hard steel is backed up with a soft ductile steel for such purposes as lawn mower

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*"The Production of Magnesium Alloys against Corrosion," by H. Sutton and L. F. Le Brocq. J. Inst. Metals. 1931 (No. 2), pp. 53-70.

†"Magnesium Alloy Protection by Selenium and Other Coating Processes," by G. D. Bengough and L. Whitby. J. Inst. Metals. 1932 (No. 1), pp. 147-163.

blades, plough breasts, etc., and recent developments are connected with the desire to use relatively expensive corrosion resisting materials merely as a facing to mild steel, thereby obtaining the valuable corrosion resistance of such materials but cutting down the cost. Both nickel and austenitic nickel-chromium stainless steels are being produced in this manner. By the development of a suitable technique and rolling methods a perfect union between the two metals is obtained.

Electrodeposition.

In connection with the actual process of electro-deposited metals attention has been directed to the question of adhesion which was very definitely brought to the fore when chromium-plating was introduced owing to the fact that the locked-up stresses in the chromium tend to cause the underlying coat of nickel to be lifted from the base metal. This resulted in serious attention being given to ensuring adequate adhesion of the nickel to the base metal and it is now possible to obtain adhesion values as high as 20 tons per sq. in. and over in the case of nickel deposited on steel. In obtaining satisfactory adhesion it is most essential that particular care shall be paid to the initial preparation of the metal before the actual plating begins, i.e., the removal of grease, the removal of oxide, and the final removal of the " flowed " layer by etching. The " flowed " layer which is produced by grinding, etc., is apt, under the influence of hydrogen generated during the plating, to result in the formation of an embrittled layer.

The modern practice is to use a chemical degreaser in which the article is subjected to trichlorethylene, generally in the form of vapour, which removes grease, oil, and the like. In certain conditions, it may be advisable to pass the article through a preliminary chamber in which it is first immersed in the liquid and then subjected to high velocity jets of trichlorethylene. After passing through the chemical degreaser the components are then subjected to electrolytic cathodic treatment in an alkaline bath followed by electrolytic anodic etching usually in sulphuric acid in the case of steel or citric acid in the case of brass.

In view of the widespread adoption of chromium-plating both for decorative and corrosion-resisting purposes, attention may be drawn to a series of exposure tests carried out under the control of a joint committee formed by the American Electroplaters' Society, the American Society for Testing Metals, and the National Bureau of Standards, in which a series of steel specimens plated under carefully controlled conditions were exposed to the following types of atmospheres for two weeks :—

Tropical marine,
Industrial urban,
Severe industrial,
Northern marine,
Uncontaminated rural and
Suburban, in various localities throughout the U.S.A.

Results* were summarised as follows :—

(1) The protective value of nickel coatings depends almost entirely on their thickness. At least 0.0005 in. is required for good protection under mild (indoor) conditions, and at least 0.001 in. for more severe conditions.

(2) The exact conditions of nickel deposition and of the cleaning and pickling have no marked effects on the protective value, provided an adherent uniform coating is obtained.

(3) The presence of a layer of copper reduces the protective value of thin nickel deposits under all conditions, and of thick deposits under severe conditions. If chromium is also present, the copper has little harmful effect in thick deposits. If the copper layer is buffed, the protective value of the composite coating is increased.

(4) A very thin deposit of chromium such as 0.00001 in., sometimes reduces the protective value, especially of pure nickel deposits. Chromium coatings about 0.00002 to 0.00003 in. add very little to the protective value, but maintain their bright appearance owing to their resistance to tarnish. Relatively thick chromium coatings, from 0.00005 to 0.0001 in. improve the protection against corrosion, especially in industrial atmosphere.

(5) The protective value of chromium over nickel of composite coatings is somewhat improved by using a bath with a high ratio of weights of $CrO_3 : SO_4$, such as 200. Deposits produced at 35°C. (95°F.) are slightly superior to those made at somewhat higher temperatures.

(6) The use of zinc under nickel makes the protective value less than that of either metal alone. Cadmium has very little effect under nickel.

(7) The use of zinc or cadmium under nickel tends to produce white stains and blisters.

Some considerable attention has been given recently to the production of a bright nickel coating with a view to saving a certain amount of time required by polishing. In the past it has not been possible to obtain bright nickel deposits direct from the plating vat and at the same time to avoid brittleness and poor adhesion. Recently

* Research Papers RP.712 and RP.724. Journal of Research of the National Bureau of Standards, Vol. 13, 1934.

solutions have been developed, however, which overcome these defects to a very large extent, but as is to be expected in any new development, it cannot be claimed that finality has yet been reached.

In Fig. 2 will be found data concerning the ranges of hardness of electrodeposited metals as at present determined. Owing to its hardness,* chromium has been used for plating direct press tools which has resulted in a very much increased output per tool and also by a process recently developed by Messrs. Fescol, Ltd., by which it is now possible to deposit chromium on to finished machine articles, the deposit having a thickness of about 0.001 in. and a diamond hardness of 1000 and over. Previous to this it was necessary to deposit chromium in excess of the required amount and then subsequently to grind, but an advantage of the more recent development will be obvious to all engineers.

Tin plating is now satisfactorily carried out using sodium stannate solutions and one application is in connection with dipped tin which is porous, and so to overcome this defect plates are given a thin coating of dipped tin and subsequently electroplated.

Casting Processes.

An outstanding development in connection with casting processes is concerned with the trouble of pin holes in aluminium castings which has been with us for many years. As a result of considerable amount of research under the auspices of the British Non-Ferrous Metals Research Association a process has now been developed† whereby this trouble can be very largely overcome and attention of all who are interested in the production of sound high quality aluminium castings is drawn to this. Briefly the process consists in maintaining a dry, hydrogen free atmosphere over the surface of the molten aluminium which is covered with a suitable flux capable of dissolving any oxide present. The molten metal is at the same time agitated by mechanical means to assist in the removal of dissolved gases.

An interesting development which is in its early stages is the direct production of sheet by the Hazelett process in which the molten metal is poured directly between the rolls.

Heat Treatment.

In the realm of heat treatment the most outstanding development is in connection with bright annealing. Annealing in ordinary furnace atmospheres has a deleterous effect on the surface of the

* See also "Electrodeposition of Chromium of Wear Resisistance" by Dr. J. Kronsbein, Trans. Electrodepositors' Technical Society, September, 1935, p. 23-

† British patent No. 435,104.

material annealed and in many cases this subsequently has to be removed either by sand blasting, pickling, or some other means, which not only takes up time and space, but also may be costly and may result in a large amount of scrap. It is, therefore, not largely surprising that as soon as bright annealing became a commercial possibility, its use has been widespread. Actually the bright annealing is achieved by controlling the furnace atmosphere either by the combustion of butane or town gas, cracked ammonia in which the hydrogen is removed by burning, the materials being so treated range from brass, copper, up to silver and gold.

Attention has been paid to the speeding up of carburising by avoiding the packing of the steel components in the usual compounds in boxes, although the latter process has still a great deal to recommend it. Of these new processes mention may be made of "Rapideep," which is a special form of cyanide liquid carburising. It is recommended principally for depths of case greater than $\frac{1}{16}$ in. and is intended to be complementary to the standard sodium cyanide-sodium carbonate bath. In Fig. 3 will be found particulars relating to typical hardness curves. A new rapid case-hardening process known as "Durapid" has also been developed which is rather different from the standard pack hardening process. The carbonising material is in the form of a thick liquid, and is applied by dipping. The component is then placed in the furnace at say 920°C. and a case is produced in a much shorter time than normally. "Durapid" contains a specially fine form of carbon and the energisers are specially prepared. It also contains a catalyst such as a metal salt.

Localised hardening in certain cases has certain advantages, and at present two methods have been devised. In one, known as "shorterising," the component is heated by means of an oxy-gas flame followed by quenching, whereas in the other process, which has been developed in the U.S.A., the local heating is effected by means of high frequency electricity.

Expansion Problems.

The wide difference in co-efficient of expansion between aluminium alloys and steel brings with it problems, especially in connection with internal combustion engines, which are sometimes rather difficult to solve. For example, it is obvious that aluminium in itself is too soft a material to stand up as a valve seat to the hammering of a steel valve and it is, therefore, essential to use a hard material in the form of a valve insert. With the adoption of a doped fuel containing tetraethyl lead it is also essential to use a material which has a high degree of corrosion-resistance, as well as heat-resistance, and also which would have a co-efficient of expansion as near as possible to that of aluminium in order to

avoid any tendency to work loose. Such a material has recently come to the fore in the form of NMC steel which has the following typical composition :—

	%
Carbon	0.7 max.
Manganese	4.0 to 6.0
Nickel	11.0 to 14.0
Chromium	3.0 to 6.0

and which has a co-efficient of expansion of 0.000021 per °C. which, as will be seen, more closely approximates to the normal value of aluminium alloys.

Another interesting development is in connection with the production of glass to metal seals which are as free as possible from strain. Hull and Berger have contributed an interesting paper in *Physics*, December, 1934, Vol. 5, pp. 384-405, on this particular problem and refer to two alloys—" Fernico " and " Fernichrome "—which have the following composition :—

	"Fernico" %	"Fernichrome" %
Iron	54	37
Nickel	28	30
Cobalt	18	25
Chromium...	—	8

"Fernichrome" matches lead and lime glasses much more closely than does the 27% chromium-iron, especially if it is necessary to anneal.

In the case of corning glasses a transition occurs which produces a somewhat irregular expansion and it is rather remarkable that the alloy " Fernico " also has a transition at about the same temperature which enables it to be matched with this type of glass over the whole range from zero to the softening point.

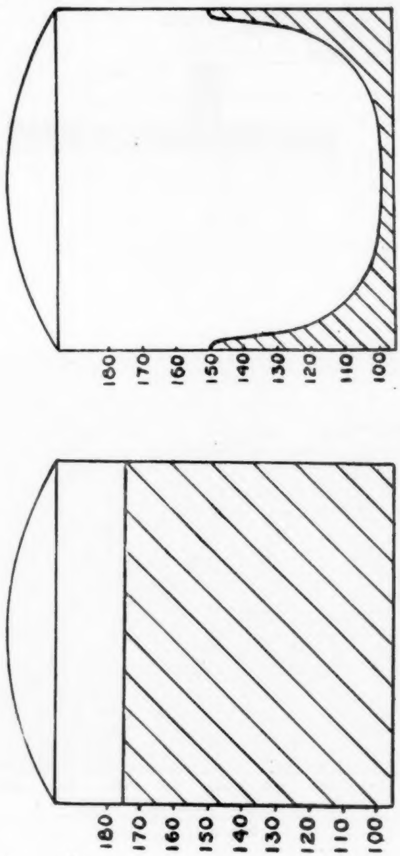
Shrink Fits.

In the case of shrink fits, instead of the necessity of heating one of the components it is now possible by using solid carbon dioxide in the form of snow to shrink one of the components very much more conveniently than is entailed by heating, since no damage is done to the material either to its properties or to its surface. The temperature available by this means is —79°C.

Inspection.

Whilst inspection is a subject for a lecture in itself mention may be made of the more extended use of X-rays in investigating defects in castings and also in the use of magnetic testing for the detection of cracks in steel components. This latter test consists of immersing the steel component, duly magnetised, in a suspension of fine iron

and owing to the interruption of the magnetic flux the iron particles will collect on any crack. This test will detect cracks which are invisible to the naked eye, and is finding increasing use both in inspection of materials prior to assembly and also in inspection during overhauls. Spectrographic analysis is also coming to the fore. One should also refer to the increasing use of the diamond hardness test such as the Vickers and Firth whereby only a very small impression is made which in most cases does not scrap the component as in the case of the ordinary Brinell, thus enabling 100% inspection to be carried out.



Cold Drawn Ordinary Brass Rod, 2 in. diam.
Hardness Across Longitudinal Section.

Temper Hardened Kunial Brass Rod, 2 in. diam.
Hardness Across Longitudinal Section.

Fig. 1.

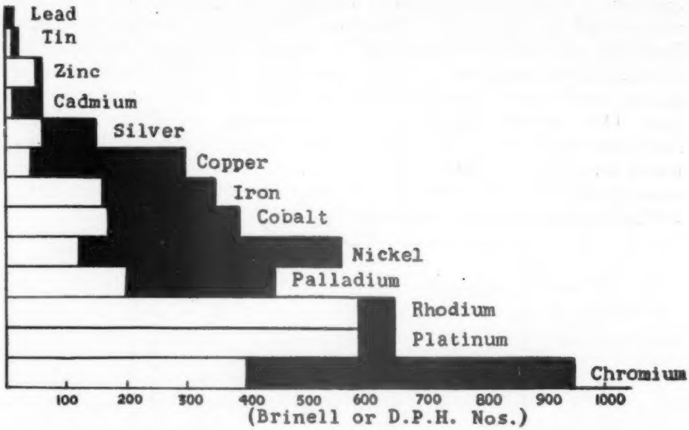


Fig. 2.

Ranges of Hardness of Electrodeposited Metals as at present determined.

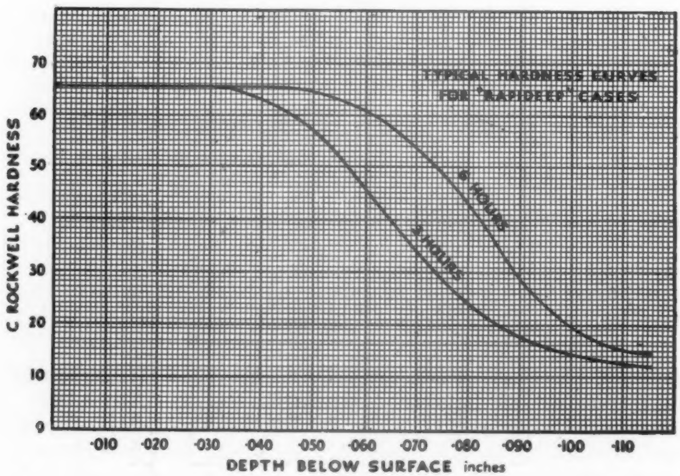


Fig. 3.

TABLE I

Mechanical properties of copper 92.5, nickel 6, aluminium 1.5%, alloy in rod form, in the softened condition and after tempering for two hours at various temperatures.

Condition	Diamond Pyramid Hardness	Limit of Proportionality Tons per sq. in.	Proof Stress Tons per sq.in.		Tensile Strength Tons per sq. in.	Elongation, Per cent. on 2 in.
			0.1%	0.2%		
Quenched from 900°C	68	1.2	4.6	5.2	22.0	48
Quenched from 900°C and tempered for two hours at the following temperatures :—						
300°C. ...	68	1.2	4.6	5.2	22.0	47
400°C. ...	125	4.0	9.3	10.9	29.0	36
500°C. ...	142	10.5	16.2	17.0	35.8	34
600°C. ...	194	17.9	23.0	34.0	44.3	20
700°C. ...	119	6.4	12.9	13.7	28.8	30
800°C. ...	80	1.6	4.9	5.4	22.0	48

TABLE II

Mechanical Properties of a Nickel-Aluminium Brass after various Treatments. Composition : Copper 72.5% ; Zinc 20% ; Nickel 6% ; Aluminium 1.5%.

Treatment	Maximum Stress Tons per sq. in.	Limit of Proportionality Tons per sq. in.	Elongation per cent. on 2 in.	Brinell hardness No.
Water-quenched	22.8	4.4	61	66
Water-quenched and re-heated ...	36.6	17.2	29	143
Water-quenched and cold-rolled (50% reduction in area) ...	39.7	11.1	6	170
Water-quenched, cold-rolled, and re-heated...	46.6	25.0	11	195

TABLE III

Effect of Heat-Treatment on a Nickel-Copper Alloy containing 30% Nickel with the addition of 1.5% Aluminium.

Treatment	Maximum Stress Tons per sq. in.	Limit of Proportionality Tons per sq. in.	Elongation per cent. on 2 in.	Reduction of area per cent.	Brinell hardness No.
Water-quenched	26.9	3.2	45.0	65	90
Water-quenched and re-heated	48.8	18.0	32.0	43	184
Water-quenched, cold-drawn, 25% reduction in area and re-heated...	58.1	31.2	16.0	38	210

TABLE IV

Mechanical Properties of a Nickel-Silver after various Heat-Treatments. Composition : Copper 65% ; Zinc 20% ; Nickel 13.5% ; Aluminium 1.5%.

Treatment	Maximum Stress Tons per sq. in.	Limit of Proportionality Tons per sq. in.	Elongation on 2 in.	Brinell hardness No.
Water-quenched	24.1	4.2	58	82
Water-quenched and re-heated ...	36.7	17.7	33	160
Water-quenched and cold-rolled (50% reduction in area) ...	45.7	12.1	6	180
Water-quenched, cold-rolled and re-heated...	55.5	29.0	6	230

TABLE V

Mechanical Properties of Standard Monel Metal compared with those of Heat-Treatable Monel Metal (K Monel).

Alloy	Treatment	Max. Stress Tons per sq. in.	Limit of Proportionality Tons per sq. in.	Elongation. per cent. on 2 in.	Reduction of area per cent.	Brinell hardness No.
Monel Metal ...	Annealed	31.3	11.8	50.0	72	120
Monel Metal ...	Cold-drawn 26% reduction in area... ...	50.2	13.6	19.5	64	200
Monel Metal ...	Cold-drawn, 26% reduction in area and strain-relief annealed	52.3	31.2	22.0	60	205
Heat-treatable Monel Metal	Water-quenched ...	35.0	14.0	45.0	65	143
Heat-treatable Monel Metal	Water-quenched and re-heated	60.0	35.0	30.0	45	270
Heat-treatable Monel Metal	Water-quenched, cold-drawn, 15% reduction in area and re-heated	76.0	50.0	20.0	30	310

TABLE VI

Physical Constants of K Monel.

Density 8.58
Weight, lb. per cub. in. 0.31
Melting Point ... ... 1315/1345°C.
Specific Heat (20—400°) 0.127
Co-eficient of Expansion :—
25—100°C. ... ... 0.000014 per 1°C.
25—300°C. ... ... 0.000015 ,,
25—600°C. ... ... 0.000016 ,,
Magnetic Transformation—Below minus 79°C.
Elastic Modulus :—
in Tension ... ... 26,000,000 lb. per sq. in.
in Torsion ... ... 9,500,000 ,, ,,

TABLE VII

Physical Properties at Elevated Temperatures of K Monel.

Temperature °C.	Maximum Stress Tons per sq. in.	Yield Point Tons per sq. in.	Proportionality Limit Tons per sq. in.	Elongation per cent. on 2 in.	Reduction In Area per cent.
25	73.6	55.8	46.9	21.0	38.9
95	72.8	55.4	46.4	21.0	37.0
205	69.6	52.7	44.6	20.0	35.0
315	65.9	48.5	37.5	19.5	32.8
425	55.8	47.3	36.3	18.5	29.8
540	55.6	45.9	31.5	9.5	9.8

TABLE VIII

Mechanical Properties of Inconel.

	Tensile Strength Tons per sq. in.	Yield Point Tons per sq. in.	Elongation Per cent.
Sheet and Strip :—			
Annealed	35—40	13—15	45—55
Rod :—			
Annealed	35—40	13—15	45—55
Cold drawn	45—50	35—40	20—30
Wire :—			
Annealed	35—40	13—15	45—55
Spring temper	78—55	—	—

TABLE IX

Physical Constants of Inconel

Density	8.5
Co-efficient of expansion :—	
100°—200°F. range :	
per °F.	0.0000064
per °C.	0.0000115
100°—1400° :	
per °F.	0.00000896
per °C.	0.0000161
Heat Conductivity	3.5% that of copper
Specific Heat (77°—212°F.)	0.109
Melting Point :—	
°F.	2,540
°C.	1,388
Modulus of Elasticity, lbs. per sq. inch ...	32,000,000
Modulus in torsion, lbs. per sq. inch ...	10,300,000

Discussion, London Section.

MR. SUTTON : I have known Mr. Johnson for many years, and I know him sufficiently well to take careful notice of his views. We were sorry to lose him from aircraft and that was indeed a blow. He has been doing very useful work for many years now and has continued that excellent work since he joined the nickel specialists. He has attempted a very difficult thing to-night in surveying these recent advances and in presenting the more important ones in an easily understandable form. I should like to congratulate him on the way he has done this.

It is a very long way from ounces in the laboratory to hundreds of tons in everyday use, and a lot of spade work has to be done by someone or other before the ground of research can be thoroughly utilised. Mr Johnson is in a position to do a lot of that spade work and has done it very well in some of the particular instances with which he has been concerned. He has mentioned quite a number of items to-night which have a very special interest for me on account of my association with aircraft, and I should like to mention one or two of them.

First there is Monel Metal K, which is attracting considerable attention in my own department now, because of its promise to prove a consistently hard and durable material which gives a tensile strength to the order of 70 tons per sq. in. and which has more freedom from magnetism than corrosion resisting steels. In the cockpit of an aeroplane we have a compass and if we start moving about a joystick with magnetic materials on it we influence the compass. We hope to find a number of useful applications of this interesting alloy in the vicinity of compasses and other instruments of like nature. Another very interesting property of that material that has come to our notice is its modulus of elasticity. In fact the alloy has a Young's modulus of 25,000,000 lbs. per sq. in., which is indeed a high figure for a non-ferrous material. Another feature of it that interests us is its very high resistance against corrosion. This seems to be very high indeed. I would like to ask Mr. Johnson whether the corrosion resistance is likely to be as high as that of ordinary Monel metal or whether we shall have to sacrifice something there for the other qualities.

As regards Kunial brass, there again we have an interesting material which is able to give apparently consistent properties. I would like to ask Mr. Johnson whether that type of brass will be susceptible to season cracking. We know that cold worked brasses are liable to crack on exposure to even mild corrosive influences

for long periods, or are liable to crack in a short time under severely corrosive influences. I would like to ask whether this Kunial type of alloy is going to be found susceptible to cracking under corrosive influences.

Nitriding, as Mr. Johnson has shown, seems to be going ahead and I was speaking to a prominent American aircraft engine designer and engineer who said that he felt convinced that even the medium-hard type of nitriding steel, the chrome-molybdinum type which hardens up to about 800 vichers, when used for engine cylinders, etc., has advantages over ordinary case hardening steels in similar applications. I would like to know whether these views are held by Mr. Johnson and whether there is anything in the nitriding case which is of real merit compared with the carbon case of an ordinary case hardening steel from the point of view of frictional properties in different parts of engines.

Mr. Johnson : I would like to thank Mr. Sutton for his very kind remarks. The low temperature treatment which constitutes the second part of the heat treatment acts in the same way as low temperature annealing in the case of season cracking, so that it can be said that Kunial brass is not subject to it. In connection with corrosion resistance of the precipitation hardening alloys to which I have referred I think that it would be advisable to await the end of long time exposure tests before giving a definite decision although the tests, as far as they have gone, do show that in general they are quite as good and in several cases definitely superior to the ordinary alloys which they have replaced.

With regard to the low diamond hardness type of nitriding steel as compared with case hardened steel I think the main advantage really is in the nitriding process in itself as compared with the case hardening process, in that it is carried out at a relatively low temperature of about 500. Thus the danger of distortion which occurs in ordinary case hardening which is carried out in general at about 900° to 770°C, is obviated, and it is possible to nitride a more or less finished machine article, such as parts of liners, etc. I do not see any great advantage from a wear resistance point of view.

Mr. Nolan : I should like to know if the lecturer could give us any information on chromador steel. I have recently been working on a design for a hydraulic rivetting machine on which the body is lubricated from chromador steel instead of in cast steel as previously obtained. The body sections are elastically welded and it has been designed for a working stress in the sections of 15 tons per sq. in. instead of the usual 5 tons per sq. in. in cast or mild steel. We are thus enabled to get 90 tons on the rivet instead of 30 tons formerly for practically the same weight of machine. In recent War Office contracts ducal steel, which is the equivalent of chromador, is speci-

fied for light bridge structures. What is the future of chromador steel and can it be developed to the extent of competing with nickel-chrome steel ? If so, what would be the comparative costs ? A big claim is made just now for copper bearing steel, due to its rust resisting properties. I have carried out some experiments on both mild steel and copper bearing steel and found no difference in this respect. Is the claim that copper bearing steel is superior as a rust resister to mild steel justified ?

MR. JOHNSON : The chromador steel is a low alloy steel of the copper-chromium type which possesses a tensile strength of about 40 tons in the rolled condition. I think in electrical welding one of the troubles which will be experienced, not only in chromador, but in several of these new high tensile structural steels, is that they are liable to hardening when heated.

With regard to rivets I was under the impression that the manufacturers of chromador make a special steel lower in carbon thus avoiding hardening up. I am rather surprised to learn that 90 tons tensile strength was found in the rivets after driving them.

MR. NOLAN : What I mean is that in hydraulic riveting work a load of 90 tons is obtained from the rivetting machine compared with 30 tons previously obtained with practically the same weight of machine.

MR. JOHNSON : I am afraid I did not hear your first question correctly and consequently misunderstood you. The possibility however of local hardening due to welding is a thing to be watched. I do not say that in every case you will get this with welding, but the possibility is always present.

With regard to copper bearing steel and the question of corrosion resistance, I think that the position is that if you test ordinary copper steel as against mild steel in the ordinary atmosphere you will not find very much difference. It is only when you have a sulphuric acid atmosphere that you find that the copper steel has an improved resistance. That is the only difference between copper bearing steel and mild steel.

MR. FAIRBROTHER : I am here to-night as the guest of Mr. Hales, and have listened to Mr. Johnson's paper with very great interest, and appreciate that his opinion and advice on metallurgical matters are of considerable value. I should like to raise a few points with regard to the application of some of these new alloys. He mentioned the nitriding of liners and similar parts with reference to distortion. The distortion which takes place is very serious and quite an amount of experimental work has to be done when nitriding those sections like rings and sleeves to ascertain the amount of distortion and to make provision for same in the machining of the parts before nitriding. It is now generally agreed that the parts should be

nitrided whilst the section is as stiff as possible, and all subsequent machining to be done after nitriding where possible.

With reference to the magnesium alloys, I should like Mr. Johnson to give a little more information with regard to his experience, as there seems to be a tendency for casting in this material to be made too light, whereas a considerable increase in sections could be arranged without having the castings too heavy, having regard to the low specific gravity of this material. Furthermore, magnesium castings do not appear yet to be wholly reliable, and cases have occurred where the condition of the material varies considerably in the same casting.

Inconel material appears to be interesting, since it is useful in cases where material is required to resist heat and corrosion. Apparently there is still a lot to learn with regard to the manipulation of this material. The lead bronze referred to by the author appears to be more of a mixture than an alloy, and the difficulty in manufacture is to keep the material free from lead segregation, which apparently can be assisted by adding a small percentage of tin.

Regarding the new steels, there seems to be plenty of scope left for development of steels for valves in high speed high compression engines using leaded fuel, as this material has to have a reasonable tensile strength at elevated temperature; it also has to resist erosion and to have a low co-efficient friction in order to operate satisfactorily in the valve guides.

MR. JOHNSON: I would like to thank Mr. Fairbrother for his very kind remarks and also for his interesting contribution. I think that the point with regard to distortion in nitriding is one of its drawbacks, especially in very thin sections, and it is a question of carrying out trial experiments to find how much you have to allow in the way of distortion and so forth.

With regard to magnesium alloys. I have not had any very recent experience actually in using magnesium alloys so I would not like to speak too definitely on this point. I would like to refer you to a recent technical meeting that was held when this same question came up. A certain member who has had a very great deal of experience in making aluminium and magnesium castings, claimed that it was easier to make sound magnesium than aluminium castings and he said that he was entirely unbiassed as he made both types. On the other hand I am interested to hear that Mr. Fairbrother has found such a very high variation in magnesium castings. I think, however, in the case of aluminium castings we should find in intricate components quite a wide variation of properties such as he mentioned.

As to the uses for various materials, Inconel is at the moment in the aircraft field being used for exhaust manifolds or exhaust

rings. It has a somewhat higher specific gravity than the stainless steels.

I was interested in Mr. Fairbrother's remarks in connection with lead bronze bearings and certainly the point he mentioned is a very important one, that is the difficulty of making bearings and ensuring evenly divided lead. It is actually very difficult to make lead bronze bearings without having a fairly high scrap.

In connection with leaded valves, the use of the M.M.C. steel has overcome to a very large extent the corrosion trouble that has been experienced with tetraethyl lead. This steel unfortunately is not one that is easy to machine, but I know of one case where it is being used for valve seats in which the threads are ground. It is claimed that the threads are produced fairly cheaply by that means and have a very good finish. I think that answers your point.

Mr. G. S. Cutts: There are two new materials now being manufactured in Scotland which would appear to be of some interest. The first is a copper-nickel composition and is manufactured under the trade name of "Bal-Nel." In appearance it is similar to pure nickel, takes the same high polish as silver, and under corrosive influences is superior to gun metal, copper, or bronze. Its maximum tensile strength is 107.5 tons per sq. in., and completely retains its strength up to 450°C. To bring the Brinell down to 100 would necessitate a temperature of at least 850°C. "Bal-Nel" can be made in bars, tubes, sheets, strips, castings, etc., and its applications are varied and numerous, i.e., steam turbine blades, resistance wire, electric cookers, and heating apparatus, etc. The metal is extraordinarily resistant to alkali corrosion: corrosive action by sea water, changing atmospheric conditions, etc., and a notable claim—can be kept clean with ordinary soap and water.

The second is "Pistonel," which is a light-weight alloy specially prepared for the construction of pistons for motor car and aero engines. It is reputed to be twice as strong as ordinary aluminium, and that its co-efficient of linear expansion is very proximate to that of cast iron. This material is also highly resistant to fall in tensile strength at elevated temperatures. Perhaps Mr. Johnson could give us more detailed technical information with respect to these two products and I should be interested to hear of their behaviour under practical working conditions.

Mr. Johnson: I am afraid, Mr. Cutts, that I have no detailed information about the alloys. I have seen in the Press reference to "Pistonel" and the claims as to its properties, but I am afraid I know nothing about it beyond that. I do not know whether Mr. Sutton does?

Mr. Sutton: I am afraid I have no personal experience of these alloys.

Mr. Ward: May I ask Mr. Johnson if there are any ill effects

on the operators when the vapour escapes. I believe such a degreasing mixture is used in the present-day clothing and cleaning shops and is used in various other shops, and I do not think it is a good thing at least to come into contact with operators.

MR. JOHNSON : As Mr. Barrow is present and he has investigated this particular point I think it would be of interest to hear his remarks.

MR. F. E. BARROW : The question of the protection of operators is one which has come to the fore where the equipment has been installed in garages and such places where gas is the only heating medium available. The complaints about toxicity are not rightly directed at the solvent but concern the products of combustion and of decomposition of solvent, which, as a result of improper operating methods, may find its way to the gas burner. At temperatures exceeding 660°C. the solvent can be decomposed with the production of hydrochloric acid gas. Industry ,in general, has available, and prefers other heating systems such as hot water, steam or electricity. These are totally enclosed and the temperature can be accurately controlled. The study of the control, not only for pure solvent vapour, but also of mixtures of vapour with air is advancing. I think in the year the German, the American and the English designers of degreasing machines have really got down to the job by providing means of condensing and recovering vapour which previously tended to leave the tank and be lost. By this means they are cutting down the quantity which could possibly approach the operator. One other point will be interesting. That is that tests have been carried out recently by chemists who have taken samples of air mixtures which are adjacent to an operator when he is actually working.

Already they have certain figures, and the evidence is still accumulating, that on an open type of degreaser the concentration which might reach the operator's nose and lungs isin the order of.03 to.04%. It is also fairly established that 4% is a dangerous concentration, but it will be appreciated that 4 to .04% is a very big change. I think that the complaints arose from ignorance when using these solvents some considerable time ago, and concentrated work has made it a well controlled method of degreasing.

MR. DOULTON : We have had considerable trouble in overcoming the dicolouration of work during the Nitration process. This was prevented by using a closely pitched bolted cover for the work container and an Aluminium sandwich joint. The work container shown on the screen this evening appeared to have a very heavy enveloping cover bedding into some kind of plastic joint. I would like to hear just how this joint is made. The next point I would like to raise is with regard to the use of Nitralloy steel in steam

valves. With high temperature superheated steam Nitralloy is probably the finest material available. However, when used with saturated steam under certain conditions corrosion may become a serious trouble. Is there any possibility of obtaining in the near future a stainless Nitralloy with otherwise the same properties as the existing material?

MR. JOHNSON: In the nitriding container the lid drops into a grove containing a finely divided powder of the diatomaceous earth type and that forms quite an effective seal. It is also very much simpler than the original method of bolting up the lid with a flange of numerous bolts, which was not always very satisfactory.

The question of the corrosion of the nitriding type of steel in steam valves is an important one and the only solution I can suggest is the fact that the austenitic type of stainless steels can be nitrided. There is this drawback however and that is that it is only possible to produce a rather shallow case which makes it difficult when it comes to the question of grinding allowances.

MR. GROOMBRIDGE: (Section President, in the chair): I should like to ask Mr. Johnson a few questions on the subject of Inconel Metal, as I would like to pursue this a step further. What is claimed for this material? Are both properties of heat resistance and non-corrosion included in this material? It has also been mentioned that aeroplane engine exhaust manifolds are now being manufactured from this material. Do you find that the welding process is perfect? Have you any information regarding the welding process if it has actually been perfected? If it is a safe job, what type of fluxes are used and how many types, if there are several? I have been informed that the method of fabricating these manifolds is by rivetting instead of welding. Could Mr. Johnson make this point clear to me?

MR. JOHNSON: Inconel is both heat resisting and corrosion resisting in the same way as the 18/8 type of stainless steel.

With regard to welding, there are certain precautions to be observed. Fluxes have been developed for arc welding which are quite satisfactory. As is the case with any welding it is essential that there should be carried out a certain amount of trial and error by the welder himself in order that he shall become accustomed to the peculiarities of the metal. The point is that whilst Inconel cannot be welded as easily as say mild steel it is possible after practice for a welder to produce perfectly good welds either by oxy-acetylene or metallic arc.

MR. AIERS: Mr. Johnson has given us a lot of information regarding the advances which metallurgists have made in producing alloys which give improved physical properties, but while these are extremely important, I should be pleased if he would give us further information concerning the benefits they have or can

give to production engineers in connection with machining of metals. Many times to-night he has spoken of improvements in copper alloys, and I should be pleased if he could give us information of any alloy added to copper which would enable it to be machined as easily as brass and other metals. Recently, I came across some pieces of copper from the continent which had these properties, and I should be pleased if the lecturer could give us some information on this point.

With regard to the machining of stainless steel, Mr. Johnson guarded his statement by saying that "so-called" free cutting stainless steel was available. While I agree that free cutting is rather a loose term, I do think that metallurgists should be able at the present time to produce economical stainless steel which could be machined at speeds equal to medium carbon steels.

The lecturer also gave us information regarding the treatment of alloys to prevent tarnishing on the outer surface. I should be pleased to hear of any preparation which could be used on brass details in place of the usual lacquer. A few years ago I tested a process of carbonising from liquid or paste, instead of the usual pack hardening, and although there was a big saving in cost, we found that we did not get an even deposit, and it was, therefore, unsuitable for the job in question. Would the lecturer inform us if, with the new process, this trouble has been eliminated. When dealing with the machining and polishing of magnesium alloys, Mr. Johnson did not refer to the trouble experienced with fires, and I was wondering if our metallurgists were experimenting with any element which could be added to these alloys, which would overcome the troubles which are experienced in this respect.

MR. JOHNSON: With regard to the machining of metals I am afraid the metallurgist is not necessarily always of very great help to the production engineer, because in general he is always searching for other properties which may not have any relation to machining. In any case it is very difficult to find any test which will tell you whether a metal is going to machine easily or not and also from the point of view of additional elements I think in America a certain material has been put forward as an additional agent to test steel for machinability, but as far as I can ascertain in this country no very great importance is attached to these materials, in that no very great improvement has been obtained, but I would like the opinion of other people other than my own on that particular point.

With regard to free cutting of copper and brass, I am afraid I have no experience on that particular point.

As regards the colour effect on aluminium obtained by dyeing, this is not possible with brass. The essential point is that it is not possible to produce on brass the same kind of anodic film as is the

case with aluminium alloys. The liquid method of carborising would be the more advantageous, for it is as I see it easy of manipulation and results in a reduction in cost of furnaces and carborising boxes, although I should say that probably for very specialised work the pack hardening might be essential.

Mentioning magnesium alloys, I am afraid I do not know of any work that has been done with a view to making additions in order to effect an improvement from fire point of view. I always remember in some works some years ago we carried out some experiments and the only way in which you could put out the fire was (apart from sand) by pouring paraffin on it, and the only trouble then was to put the paraffin out. It was, however, rather remarkable to find that paraffin poured on to blazing magnesium would immediately stop the magnesium burning. Tests with the usual fire brigade materials such as Foamite, tetrachloride, and the like only aggravated the burning magnesium.

Mr. Groombridge: I think I can answer that question, Mr. Aiers. I have instituted a system in our factory whereby pails of powdered asbestos are kept in close proximity to the machines being operated, and have proved that this material if thrown over a fire will put it out immediately!

A Visitor: With regard to the non-corrosive treatment of aluminium I notice the lecturer mentions a treatment with sodium carbonate and sodium chromate. I would like some information as to how it is carried out and what effect it has on it.

Mr. Johnson: The British Aluminium Co. issue a brochure giving full details about this process, which is the M.B.V. process. I would suggest that if you would care to write to them they would certainly give you the booklet describing it fully.

Mr. Hales: It is my pleasant duty to propose a vote of thanks to our lecturer this evening. He has given us quite a lot of the latest information on developments of materials, based on research work of a metallurgical nature. What has come to my mind in listening to his lecture and the subsequent discussion, is the fact that we appear to have great need for some liason between metallurgical research and production engineers. The information given to-night is valuable and members, in this case, cannot contribute to the value of the paper in discussion as is the case on other subjects. Before we can use the information given to us, we must know something more of the application of new materials from a production point of view. It would appear essential to both the manufacturers of such materials and the users, viz., the production engineers, to find some means of carrying out research work, as regards application and manipulation, since the success of new materials must depend on their application and the cost of machining, etc., in practice.

A cordial vote of thanks to Mr. Johnson was adopted.

Discussion, Birmingham Section.

MR. I. H. WRIGHT : Mr. Johnson spoke, in connection with the copper-lead bearings that we are all being threatened with nowadays, about the process by which the thin steel sheet is treated, presumably on one side, with this copper-lead bearing metal. I should like to ask how thick this copper-lead film is on the steel, and whether the steel coated in that way is available on the market in any other form than in pressed form for automobile bearings ? I am thinking more particularly of the possibility of obtaining sleeves, say 1 in. bore and 2 in. long, or 3 in. bore and 4 to 5 in. long, which is simply rolled into a sleeve for inserting into the bore in a solid casting.

MR. JOHNSON : As far as I know, the process has only been carried out in America. I do not know whether it has been developed in this country yet. The order of the thicknes is quite low, a matter of $^1/_{32}$ in. I do not see why it should not be possible to form it into the sleeves that you have in mind, although the fact of having a dividing line down the sleeve might be detrimental.

MR. BUCKNELL : Is the de-gassing process mentioned with the copper-aluminium alloys equally applicable to silicon-aluminium alloys for die-casting purposes ? Will it be beneficial ?

MR. JOHNSON : It is applicable to practically the whole range of alum alloys. It is covered by a patent under the control of the British Non-Ferrous Metal Research Association so anybody wishing to use it would have to get a licence from that Association. It certainly is very beneficial if it is important to produce high-grade aluminium castings. There are obviously quite a lot of applications where a certain amount of porosity does not matter, but where it is important, say in pistons and cylinder heads, then it is a process to be considered.

MR. E. P. EDWARDS (Section President, in the Chair) : I do not know whether there are any members in the room who have had experience of gravity die-casting. I had some experience with it about twelve years ago, and very well remember that the process was almost rendered uneconomical by this question of pin holes. The scrap was often as high as 50% or 60% in parts that had to be free from pin holes. At that time the process was not developed to its present state ; if it had been, it would have been economical, but it had to be abandoned finally and pressure die-casting substituted for this very reason.

MR. BOLTON: I expect most of the gentlemen here have had some experience of the kind of work being done on alloying cast iron during the past few years. Up to about ten or fifteen years ago, the strength of cast iron was very poor, possibly not more than 12 tons per square inch, and since that time, partly by the better

understanding of the iron itself and by the use of small amounts of alloy, nickel, and chromium, it has been possible to obtain strengths quite regularly of 15 to 20 tons, and even as high as Mr. Johnson mentioned to-night, 30 tons per square inch by special processes.

We have also these new heat-resisting and corrosion-resisting irons mentioned by Mr. Johnson. Unfortunately the price of these irons is rather high. I do not think it is possible to use a good corrosion-resisting or heat-resisting cast iron much under £9 or £10 per ton, owing to the large amount of alloying elements needed. In that Ni-Resist, the nickel-copper corrosion-resistant iron, which also has quite good heat-resisting properties, 14% nickel is required and 6% copper. With Nicro-Silal, which is a heat-resisting iron developed by the Cast Iron Research Association, the nickel has to be higher, 18%.

Those two irons are, however, being used in a number of applications, and they have proved to be very economical if the application is suitable. For instance, Nicro-Silal has been used for salt baths for heat treatment purposes, and also for furnace parts used in annealing, and things of that description. Temperatures up to 900°C. can be resisted very well indeed. Ni-Resist has found many applications, such as valves for corrosive and erosive liquids, and there are other applications which are now being developed with very promising futures, using nickel as an alloy. Years ago, if very hard iron was required it was usual to use an ordinary cast iron and chill it, and in that way it was possible to get up to a Brinell hardness of about 500. If Nickel is added, say 6%, it is possible to get an iron that will chill white in the ordinary way, and also have an age-hardened structure as well. These irons are known as Ni-Hard, and the hardness on the surface can be a hard as 700 or 800 Brinell. Irons of that type are being used in applications where great wear-resistance and abrasion-resistance is required.

Mr. Edwards: Some of the members present drive cars, and some, probably, have used "doped" petrol, or tetra-ethyl-lead. I am wondering if any of you can tell us of any experience you have had with burnt out valves as a result of it, and whether you have tried valve seats made of the nickel-chrome-manganese alloy which Mr. Johnson spoke about. I have no experience of it myself, but it is rather an interesting point. We are told what an advantage it is to use "doped" petrol, but the advertisement never tells us about the effect on the valve seats which has been referred to by Mr. Johnson.

Mr. Wright: In the beginning of Mr. Johnson's paper, he spoke about the precipitation hardening whereby certain alloys which are naturally very soft can be made very hard and strong. I have

nothing to do with that kind of alloy, but I have heard from our lecturers of the existence of such alloys, and know they are used. What I would like an opinion on is the permanency of these highly artificial structures which are raised up by this peculiar treatment, and which results in such great strength. Mr. Johnson referred to it as an ageing or sort of process equivalent to ageing. We have not found any means of stopping ageing when it is desirable in human beings. Does the ageing in these materials continue and reach something like the same result as it does in human beings after some time, or can he really assure us that the very thoroughbred conditions produced are permanent, and that our grandchildren, say, won't find things made of the materials produced now breaking down ?

I should also like to testify to a very advantageous use of hardened cast iron, and that is in jig bushes for boring bars. I do not say it would be very good to run twist drills in, but the changeable bushes used for boring bars in jigs of any considerable size are advantageously made of hardened cast iron. If one runs a close fitting bar in the steel bush, and with a close fit, probably much less than ordinary lubrication allowance of usual running journals, it only needs the smallest bit of grit or change in temperature to start roughing of the bore in the bush when they are both made of more or less similar grades of steel. If the bush, however, is made of hardened cast iron, it seems to live through incidents like that very much better, and we have found hardened cast iron very advantageous in that way.

Mr. Johnson : With regard to permanence, the duralumin type is quite permanent. This alloy has been in use for twenty years or more, but with the later types of alloy which have only been introduced in the last five years, it is obviously rather difficult to say how long they will last. Actually, if you plot the figures in Brinell hardness against the time, you will find the Brinell hardness increases rapidly at the first, and then the curve flattens off until eventually it becomes parallel to the time, and there is then only a very slight increase over a period of years, although the increase over the first few days is quite rapid. I think it is fairly safe to assume that the ageing will eventually peter out. We merely assume that—we do not know.

Mr. G. A Wood : I was interested in the lecturer's remarks on the Fescol process. I was not quite sure whether he said that the Fescol process now can be produced merely by grinding, as differing from the old process where you had to turn it first and then grind. I should like to ask how they get over the difficulty of depositing chromium directly on the steel as against the method for corrosion resisting where you must have an undercoat of nickel ?

Mr. Johnson : I think perhaps I did not make myself clear in

the paper. The older way of using chromium is to deposit it thicker than is required and grind it down to finished size. The latest Fescol process, I am informed, deposits chromium 0.001 in. thick, very accurately, and therefore you can take a final machined component, minus .001 in., and then deposit the .001 in. of chromium on to it and ensure that it is accurate. There is, therefore, no need to do any final grinding. The conditions used for depositing chromium for abrasion-resisting purposes differ from that used for decorative purposes. It is principally for abrasion resistance and wear resistance that the deposit is relatively thick, but in the decorative, bright finish, it is not practical to put it on thick, and consequently you must have an undercoat of nickel to prevent corrosion as a result of the seepage of corrosive liquids through the pores of the thin chromium deposit.

A MEMBER: Is the state of the metal the same in each case? Is hard chromium the same type of material as soft chromium?

MR. JOHNSON: Yes, only it is the amount of hydrogen which is incorporated in it which produces increased stress in the chromium and produces hardness. Actually pure chromium is more or less soft, but because you have a lot of hydrogen incorporated, during the depositing of the chromium you get these intense locked-up strains which give you high hardness.

MR. PEARSON: Can the lecturer tell me whether it is possible or if anything has been done in regard to cold working of steel to prevent work hardening? Are there any modern developments?

MR. JOHNSON: I am afraid I do not know of any processes, as you are up against the laws of nature. The case of lead is a different matter, because the room temperature corresponds more or less to its annealing temperature. In the case of steel the annealing temperature is of the order of 650°C. and upwards, and therefore cold working is bound to give an increase in hardness.

MR. EDWARDS: Mr. Johnson spoke about the application of Fescol. I had some practical application some years ago in the manufacture of petrol pumps where we had to use a nickel plug in the main valve. You will all be familiar with the petrol pump as seen on petrol stations, and will understand that it is extremely difficult to get a petrol-tight joint. It was done with a Fescolised valve, and I well remember we used to have to put on the Fescol something like a ¼ in. thick to grind off at least three-quarters of it, and it was very expensive, to put on all that chromium and then to grind such an amount of it off, which of course was wasted. It is very interesting to me to learn that one can now deposit a thin coating of Fescol. It will, of course, cut down the cost enormously.

MR. THORNELOE: I should like to know if the addition of nickel to cast iron or some of the other alloys reduces cooling stress in

cases where castings are left for weathering, say, for a month after they have been rough machined?

MR. JOHNSON: I cannot say that it does. The tendency now is, I believe, to resort to artificial ageing rather than the old-fashioned way of leaving cast iron weathering for several months, and I have heard a theory put forward that this accounts in some ways for the larger wear being found in motor cylinders. I have also heard a theory put forward that you get a better cylinder wear life after it has been reground, because the metal has had time to age more or less naturally in the engine. I cannot vouch for this personally, but am just passing on the information.

MR. WEBB: Referring to Mr. Johnson's statement that it is necessary to nickel-plate before chromium plating, I have been informed that if the chromium-plated surface gets damaged, it is impossible to remove the chromium plate without removing the nickel plating, and if you attempt to remove the nickel plating you scrap the job. I should be happy to be informed that is not so. Can Mr. Johnson tell me of any nickel alloy suitable for a melting pot for silicon-aluminium which is not subject to attack by sodium?

MR. JOHNSON: It is essential to remove both chromium and nickel before starting again, but it is possible to remove both chromium and nickel without necessarily scrapping the job, although it is costly. It is the normal procedure to remove the chromium in one solution and then the nickel in another. With regard to a suitable melting pot for silicon aluminium, I may say the furnace makers have tried a series of materials and I do not think anything suitable has been evolved. At one time it was thought that calorising steel pots would be the best solution but there is the danger of local penetration owing to the presence of initial surface defects, and therefore the final advantage is not so great as it would appear. Heat-resisting steels do not seem to stand up any better owing to attack by the aluminium.

A VISITOR: What do you consider is the best material to be used for melting a silicon aluminium to resist attack? We have found the cheapest and commonest is the best—cast-iron.

MR. JOHNSON: Yes, cast-iron has been proved to be better than steel. You might get longer life by using some of the ordinary nickel chromium cast irons which have a certain amount of heat resistance, and which would resist a little bit better the cutting action of the flames in oil or gas fired furnaces.

MR. MCNAB: I should like to be enlightened as to the analysis of the material used in the cast iron crank shafts or semi-steel crank shafts, and the cost of that material relative to using steel. I should also like to be enlightened on the recent developments in Nitralloy. I understand that it is now being made with a nickel-

chrome content, thereby getting greater hardness of the core or the body of the tool.

MR. JOHNSON: I think the cast iron or semi-steel crank shafts you have in mind are the ones used by Ford. There have been quite a number of articles describing the Ford Process in the technical press recently and I think the best thing I can do is to refer you to those. I can give you references. The articles give composition, method of heat treatment, and the whole history of the experiments, also the saving over the ordinary crank shaft. With regard to Nitralloy, I really covered that in my lecture when I referred to nitriding, and when I referred to some recent developments with chromium, nickel, and vanadium and others. The surface hardness is lower than it is in the standard steel, the idea being that with the ordinary Nitralloy case it is rather brittle and apt to flake. Therefore different composition have been developed which I showed in a slide, in order to produce a tougher case, a case which would stand up to impact.

Mr. McNAB: I was wondering whether, in the case of the Ford crank, it was the design that had forced their hand rather than economic advantages obtained?

MR. JOHNSON: I think it was that they wanted to cast the balance weights integral with the shaft, and very often in the case of forgings that is a very difficult machining operation. Actually Ford claims that the cast crankshaft is 7% cheaper than using a forged one.

MR. J. W. BERRY: There were one or two points which were of great interest to me and many others, I dare say. One was with regard to copper-lead. I understand that one of the great difficulties in the use of copper-lead is to prevent segregation of the lead during casting, and even later on if the bearing is subjected to excessive heat. Another point is in regard to Ni-Resist iron. Has that yet been developed as an acid-resisting material, say for sulphuric acid 6% at boiling point? One very advanced foundry put forward what they considered the ideal iron for pickling purposes, and then a fortnight after they very honestly came forward to say that the metal had failed. I happen to know the works in which these experiments were carried, and I understand that a sample of this iron was put into the pickling vats and left there for three weeks without any serious effect upon the metal. Later cradle guides were made from the same material, and disintegrated in about three days. The failure was thought to be due to friction effects. I should like to know if the lecturer has any information on that point. Referring to Ni-Hard, I believe that it is now being successfully used in the manufacture of rolls, and I do know one pair that has been in test now for three months, and they promise to give equal service to the nickel-chrome hardened rolls. If so, it would be a great boon to people interested in that particular difficulty because

the delivery alone of the nickel-chrome hardened material at present is in the region of twelve to fourteen weeks and a breakdown under those conditions is an almost impossible thing to contemplate. I have pleasure in proposing a very hearty vote of thanks to Mr. Johnson for his interesting and instructive lecture.

The vote of thanks was cordially adopted.

Discussion, Edinburgh Section.

Mr. A. Peet (in the Chair) : I would ask you, Mr. Johnson, with regard to fescolising processes—I have had a good deal to do with them, but never in connection with gears—is it possible to fescolise gears ? In connection with magnesium alloys, I believe it is necessary in some cases for various baths to be given to the unmachined faces. There is another point in regard to the " Rapideep " case hardening. I would like to know the time it takes to do in comparison with the ordinary pack or carborising, and whether it is really as efficient as the pack method.

Mr. Johnson : Fescolising of gears—that will depend to a certain extent on the type of teeth, because chromium has a very poor throwing power and whilst you can get the thickness on the outside or top edges of the teeth, it is rather doubtful whether you can get it thrown down in between the teeth. That is the real drawback, I think, to the possibility of chromium plating. Magnesium—there is only one bath as far as I know which will prevent corrosion both of unmachined faces and machined faces, especially if the component is to come anywhere near sea water. Actually I have given particulars in the lecture of the actual bath. The " Rapideep " process—it is claimed that this shows a very considerable saving in time compared with pack hardening. I haven't got any actual comparative rates with me, but I would like to suggest that you should approach the makers of " Rapideep," who will be pleased to furnish them. The main thing, which appeals to me, is that you can avoid any scale getting on the surface of your work, because you can keep it out of contact with the air. Where there is no subsequent grinding, this latter advantage is most important, as it avoids any surface decarborisation which would be detrimental in the case of highly stressed gears.

Mr. Corbett : On the question of bright annealing, I notice that Mr. Johnson referred to removing the hydrogen. I understood that with some of the nickel-chromium alloys hydrogen was used considerably in bright annealing. Am I to understand now that this is being done away with and other reducing agents are being used ?

Mr. Johnson : Whilst hydrogen was used at one time, it is now the practice to use cracked ammonia.

Mr. Mittell : With reference to copper steel, does the addition of copper affect the corrosion resisting properties ?

Mr. Johnson : When tested under ordinary atmospheric conditions, as you would get out in the country, it does not show very much improvement compared with ordinary steel, but in the town where you get acid in the atmosphere, especially sulphuric acid,

then the copper steels do show a very marked improvement over mild steel. The amount of copper generally added, i.e., about ½%, does not affect the properties very much. The 40 ton structural steel has present not only copper, but chromium and a higher carbon content.

MR. MITTELL: I had in mind tubes, small tubes.

MR. JOHNSON: The amount added to resist corrosion is only ½% and so won't affect your properties.

MR. PEET: Mr. Johnson, can you tell me in anodic treatment what is roughly the thickness that is given for anodising the various alloys, and what is the life of the wear when a part is anodised?

MR. JOHNSON: I do not know that I can give you the life. The thickness given is about two or three thousandths of an inch, which is very, very thin. But the anodic coating is slightly porous and it is advisable to rub lanoline into your work, or some similar grease, to fill up the pores. This very considerably prolongs the resistance to corrosion. Some of the examples of aluminium which have been anodically treated and then dyed are certainly very pleasing, and for indoor use quite effective. I am afraid I have had no experience of the actual life of anodically treated aluminium when exposed to atmospheric conditions.

MR. BURNS: I enjoyed Mr. Johnson's talk, but I have to confess that he was just speaking a bit beyond me, but I will have much pleasure in reading the paper and possibly following it much easier, but one thing occurred to me, and always has, the use of rustless or stainless steel for cutting, and I just wondered if Mr. Johnson could tell me whether they have now obtained a steel which will give a good cutting edge and stand up to say, a very high speed cutting steel. I am not thinking so much of steel for cutting cast iron, but of the application of rustless steel for cutting of rubber, where any rust deposited on the article cut is inclined to damage it. I have been trying to get a stainless steel which would be suitable; one finds that it won't stand up to the same cutting as the ordinary high speed steel.

MR. JOHNSON: I am rather afraid that the cutting tool you would use would be a straight chromium steel, such as used for cutlery, but I am afraid you cannot get the same cutting edge with that as you can with the other types of steel. That is one of the drawbacks. I do not know of any definite improvements in that particular direction.

MR. CORBETT: In some very high carbon steels a small percentage of about .6% of chromium is added. Does the lecturer consider that this is absolutely necessary, or does he think that it is just a selling point?

MR. JOHNSON: In the case of high carbon steels it is usual to add a small percentage of chromium in order to prevent some of

the carbon, which is present as carbide, breaking down into graphite, and so producing a steel which would be softer than would normally be expected.

MR. CAMPBELL : I would like to ask Mr. Johnson if he could add something further as to the type of furnace he would specify for bright annealing. It is in connection with gas plant; what would you specify for that particular job ?

MR. JOHNSON : The solution to this to some extent is rather in the hands of the manufacturers, but I personally would specify an electric furnace, as it lends itself much more readily to atmosphere control.

MR. MITTELL : Why is it Staybrite steel can keep the polish for years, and yet stainless steel after about four or five months loses the bloom ? Staybrite always remains polished. Just why is that ?

MR. JOHNSON : There is a distinct difference in composition and physical condition between Staybrite and ordinary stainless steel. The former contains 18% chromium and 8% nickel, low carbon and small percentages of such elements as tungsten, titanium, etc. Ordinary stainless, i.e., cutlery steel, contains about 13% chromium and about 0.3% carbon. In order that the chromium stainless steel shall be corrosion resistant it must be used in the fully hardened condition and must be polished. Staybrite, on the other hand, is corrosion resistant, irrespective of surface condition, and moreover has a very much wider range of corrosion resistance.

MR. ALLEN : With regard to F.S.T. and F.D.P., these steels have an expansion almost equivalent to copper. What I am thinking about is using a thin sheet of stainless steel to wrap around a cast iron cylinder which is steam heated, and then welded. Now when the steam is applied to the cylinder, would the stainless steel leave the cylinder, would it expand, or become loose on the cylinder ?

MR. JOHNSON : You would have to stretch the stainless steel elastically in tension before welding, so that when the cast iron expanded you would still have a tight fit. I do not know whether it is a very practical proposition to do this, but that would be the only way to overcome the differential expansion so far as I can see.

MR. PEET : Well, gentlemen, if there are no further questions, I should like to propose a very hearty vote of thanks to Mr. Johnson for coming here to-night and giving us this interesting lecture, and I am sure I can say on your behalf that we have all enjoyed it—I know I have—and we hope that we will see him at this Section of the Institution probably again another time.

MR. JOHNSON : Thank you.

Discussion, Preston Section.

Mr. Hodgson (Chairman), mentioned that one slide had been shown which demonstrated that brass which had been hardened, when machined, came down to practically normal hardness, whereas if one of the special precipitation alloys was used, the same hardness was obtained right through. But by cold working it was possible to obtain still greater hardness. He asked whether by double machining, by taking the skin down the outside, the extra hardness would be taken away.

Mr. Johnson replied to Mr. Hodgson's question to the effect that he ought to have explained in connection with the interposition of cold work that this was really more applicable to sheet and strips and his remarks were not intended to apply to material in bar form.

Mr. Skipper referred to leaded bronze bearings and copper lead bearings, and asked whether any development had been made with a cadmium base alloy to serve the same purpose as the copper lead. Also dealing with magnesium castings, was the cost of heat-treating warranted by the benefits resulting? It was known, of course, that tensile strength was increased, but he was anxious to know whether a corresponding fatigue value was obtained.

Mr. Johnson replied that a certain amount of work had been done with cadmium base metals. The initial work was done in America. Two types of alloys were investigated: the main base was cadmium: in one case it was 1.33% nickel, and in the other 3% nickel. The investigators who carried out this work (Messrs. Swartz and Phillips) claimed rather remarkable properties for this metal, and compared with the standard white metal it compared favourably at higher temperatures, etc. He thought that experiments with copper, and in some cases silver, additions had also been tried with the cadmium base. It was certainly a harder alloy than the white metal, and it was also claimed that it bonded fairly satisfactorily with a steel back.

With regard to magnesium castings, the lecturer agreed that heat treatment was a laboured and costly process which was a big point in its disfavour. It was probably not worth going in for unless in the case of aircraft work where it was essential to get the last ounce of weight and strength and so forth.

Mr. Wilcock asked the lecturer if he could give any opinion on the question of tempering the chromium deposit in such a way as to improve the edges of gauges. At present the chromium plating was apt to snip or crack or flake off and on many occasions the component on which the gauge was tried was damaged as a result.

He, therefore, wondered whether it was possible to have the chromium deposit at a lower degree of hardness at the edges.

MR. JOHNSON's reply was to the effect that it was possible to exert a certain amount of control in plating in order to vary the hardness, but he thought directly the hardness was reduced the value of the chromium for use with plug gauges was destroyed. He mentioned that recently a paper was given before the Platers' Technical Society on the question, and if Mr. Wilcock was interested in the process, he would be pleased to forward him a copy of the paper referred to.

MR. BAILEY asked if the lecturer could offer any opiniion as to the production of an alloy rivet which would take the place of the soft aluminium or duralumin type rivet : a rivet for instance which could be employed with safety—in other words one which did not edge when hit by the riveting hammer and possibly which did not need any heat treatment. This had always been troublesome so far as the duralumin rivet was concerned. Also with reference to the Budd Shot Welding Machine, he wondered whether any particular steels had to be employed in connection with that type of welding. Again, he had not been able to follow quite clearly the lecturer's statement that shot welding could be employed on a standard type machine.

MR. JOHNSON replied that the Budd Shot Welding was orginally developed to use 18/8 steel, because it was claimed that no weld decay resulted in the weld. With the introduction of the weld decay-proof type of steel, the Budd Shot Welding process was not quite so necessary. With regard to rivets, aluminium of the type which would harden up by cold hardening might be suggested, that is such materials as M.G.7 or the R.R.66 alloys, provided the composition was somewhat modified. This would overcome any objection to using heat-treatable type of material.

MR. HOOD paid tribute to the lecturer for his excellent paper. The Production Engineers themselves, unfortunately, were more closely wrapped up not with M.G., and other types, but with the "N.B.G." Group, thus requiring insight in obtaining production. Could the lecturer say whether there was any method of treating tungsten carbide steels just before they passed into the machine shops, so that the life of any particular group of steel could be extended considerably beyond what was usually obtained ?

Another point had reference to the hardening of cam-shafts. Could these be made the last operation instead of having to go through the process of stripping, setting, and so forth ? There was also the question of valve inserts. At the moment there was a lengthy process in use which endeavoured to give almost everlasting life to valve inserts in I.C. engines. The process consisted of welding or the adhering of stellite on to a turned steel insert,

followed by a lengthy process to obtain a gloss finish. He was anxious to know whether the various alloys could be treated in such a way as to eliminate that process altogether. Also was there any simple process of treating sheet metal so as to eliminate the erecting of 'bus bodies followed by stripping because of some fault in the sheet metal, resulting in certain sections having to be thrown away as useless? Was there any method of treatment to ensure a very much longer life of the metal?

MR. JOHNSON said he would not like to make any prophecy that the trouble with the crank shafts could be overcome, as if the shape of material was altered, say by forging, there was always a tendency on the part of the material to revert to its original shape, and, therefore, some kind of distortion was almost inevitable. He could not help very much with regard to the question relating to the treatment of tungsten steels before passing on to the machine shops. He had purposely avoided the question of machine tools, as a subject with which he was not *au fait*. He understood that a lecture either had been given to the Institution, or was to be given, on this subject. It was certainly an interesting subject for research.

Referring to valve inserts, he had mentioned in his paper the use of a steel which was definitely a new development for this purpose, and which appeared at the moment to be the most promising type of valve seat which could be used under modern conditions. The lecturer said that as progress was made in one direction, one found drawbacks in another direction, and so far as he could see whenever a new material was produced which had rather marvellous properties in one direction, the law of averages stepped in and the material had certain drawbacks in another. It almost made him wonder if it was not a law of nature for the law of averages to operate.

Between mild steel and stainless steel there was no intermediate product which was intermediate in price and in corrosion resistance. Therefore, it was compulsory to go right over to stainless steel for corrosion resistance and these steels were admittedly expensive. He could only suggest some form of electro-deposition on the sheet or dipping process or galvanising.

MR. PERKS thought most of those present were interested in machineability, and the new materials which were likely to come along into machine shops introduced that question. He asked if metallurgists were considering in the production of new materials this question of machineability and were endeavouring to formulate a measure for it.

With reference to the drilling of rifle barrels at the Arsenal at Enfield, troubles were experienced in the shops there owing to the differences in machineability of material supplied by various steel makers, although all the steels contained the same chemical con-

stituents. The application of stellite to valves was not a new process, as the Americans had been using it for a long time. One of its advantages was that in addition to being cast, it could be welded, provided the operator possessed the knack and blowholes could be eliminated.

MR. JOHNSON was glad to receive this question of machineability. He felt it was one which the Institution should deal with. He had had the question raised to him previously, and had personally searched endless textbooks and papers with the object of securing useful practical data with regard to the machineability of these materials, but found that such data did not exist. He thought the Institution should form a Committee to draw up data of this kind. In his opinion it would tend to increase the status of the Institution if authoritative data sheets could be issued with regard to the machineability of different types of materials.

He was afraid it was rather difficult to discuss machineability of steels used for rifle barrels without being able to examine actual samples of the steel. Attention was, however, now being given to obtaining uniform properties in steel, both in the U.S.A. and here, specifying grain size, which not only affected machineability, but also the properties in the heat-treated condition. The lecturer said he believed that it was the general practice in this country to weld stellite for valve seatings, and not to cast it.

MR. THOMPSON asked with regard to the question of chromium plating of brass tools, if a tool hardened to give Rockwell 62 were chromium plated to about 1000 what the length of life would be.

MR. JOHNSON replied that it was still necessary to have a high hardness in the base metal in order to support the chromium itself from being crushed under the arduous conditions of service. Chromium did not tend under pressure to unite with steel.

With reference to the question of life, the lecturer quoted an instance he knew of where a very large increase in the yield of components had been obtained from a chromium plated die, and the die was still in fairly good condition.

MR. HOOD believed that it was necessary to learn how to control these new alloys, and the idea of the research departments was to illustrate and teach how these things could be used. If, as the lecturer had said, there was a possibility of treating steel in such a manner, then they wanted to know a little more about it. The lecturer had touched upon case hardening, the control of elongation, and the control of depths of hardness and distortion. He wanted to know a little more about this control business, because that was the solution of a lot of trouble to engineers. Distortion and elongation resulted in an article after hardening which was entirely different from what it was previous to that process. Was this method of hardening going to do away with this bugbear of distortion ?

MR. JOHNSON, in reply, said that precipitation hardening could not do away with case hardening, but only with the ordinary hardening and tempering. He considered that one was bound to get distortion with heat treatment : this was due to physical laws. The only thing possible was to endeavour to keep distortion as consistent as possible, so as to be able to allow for it.

THE CHAIRMAN said he thought the question raised by Mr. Hood, namely distortion, was certainly a bugbear. He thought everybody realised that there was bound to be a certain amount of distortion. The trouble was that it was not possible to get a certain article to "give" the same amount each time. He did not know whether this question was wrapped up in any way with this new grain size discovery. This grain size matter brought in the question of machining about which there would be more conflicting ideas again. A few years ago the view was expressed by the Americans that large grain size was perfect for easy machining.

MR. JOHNSON said he thought it was necessary to bear in mind the fact that in casting large ingots used in steel making, it was very difficult to guarantee that the composition is exactly the same all over. A certain amount of segregation was bound to occur : so that stampings from various parts of the ingot must vary slightly : and moreover during heat treatment they are not all quenched at exactly the same temperature and do not strike the water at the same angle, and there are other points like that, all of which tend to produce variability in distortion.

NEW MATERIALS AND ALLOYS IN THE FIELD OF ENGINEERING.

Paper presented to the Institution, Manchester Section by A. P. M. Fleming, C.B..E, M.Sc., M.I.E.E.

Mr. President,

I AM very pleased to have the honour of addressing you and appreciate very much the honour of being invited to give this lecture. On this question of materials and processes on which I want to talk to you to-night, I have divided my lecture into four parts. I want to talk, first of all, about materials, then processes; I want to deal to some extent with measurement, and then to speak for a few minutes on theories of matter.

Engineering firms are continually being embarrassed by the many innovations in the way of materials and processes that are continually coming forth, in fact in a large concern such as that with which I am associated, it is not an exaggeration to say that we get at least one new material or process put up to us daily, and all have to be investigated for the very few that are of real value.

I have classified the materials about which I want to speak, as follows :—

(1) Cutting materials—hard metals; (2) high pressures and temperatures; (3) corrosion resisting; (4) light alloys; (5) die casting; (6) magnetic; (7) conducting; (8) insulating; (9) synthetic resins; (10) miscellaneous :—light sensitive, rectifying, soundproof.

(1) Cutting Materials.

As regards tool steels, in earlier days tempered steels and steels that self-hardened with the heat of cutting, were used. These were replaced about 1900 by high-speed alloy steels. In 1926 the new carbide steels for tool tips were introduced. Carbide materials are now made all over the world under various trade names: "Widia," "Carboloy," "Ardoloy," "Cutanit," etc. Broadly speaking, they all come under three groups: tungsten-carbide, tungsten-titanium, and tantalum carbide.

The methods of manufacture for these are all pretty much the same; the carbides are prepared by heating the metals or their oxides with finely divided carbon in a hydrogen atmosphere. They

are then mixed with a binder such as nickel or cobalt and pressed into bars. These are heat treated at low temperatures to allow handling. The bars are cut into tips by means of thin cutting wheels. The tips are sintered in a vacuum or hydrogen at 1400° to 1500°C., when the tip becomes glass-hard. It is then attached to the carbon steel shank by a copper bond and the tool can then be ground on soft silicon carbide wheels.

For cast iron, tungsten-carbide steels give the best performance, and for steels, tungsten-titanium. As regards alloy steel tools, cobalt, tungsten, chromium, molybdenum, and vanadium are all used, but their performance is not equal to that of the cemented carbide tools.

(2) Steels for High Temperatures and Pressures.

Modern steam practice is tending to increasingly higher temperatures and pressures, which have necessitated the development of special steels suited to these conditions. The particular requirement is that at such temperatures and pressures the steel shall not deform or "creep." The employment of 1% molybdenum has been found to increase the resistance to "creep" by 100 to 200% for temperatures up to 450 or 550°C. Castings, forgings, tubes, etc. are made in 0.5% molybdenum steel, and for the construction of steam turbines and boilers for high temperature and high pressure plant, 0.5% molybdenum and 1.0% chromium steels are used. When operating at steam temperatures up to 500°C. it is not surprising that pronounced structural changes are brought about in the steel by service conditions. These changes in structure are accompanied by a certain amount of weakening of the materials, due to the inability of the grains to continue to adhere, and much research is being carried out at the present time directed to improving the grain boundary endurance of steels required for high temperatures and pressure work.

(3) Corrosion Resisting Materials—Ferrous.

Modern corrosion resistant steels were first introduced by Brearley who, in endeavouring to find a suitable steel to resist the erosive action of the propellant gases in gun tubes, found that specimens containing a high percentage of chromium resist corrosion. As a result of this work the stainless steels containing from 12 to 14% chromium, now so extensively used for cutlery, etc., were introduced. About the same time Krupps developed a non-magnetic steel with 18% chromium and 8% nickel, which was the fore-runner of the "Staybrite" and "Anka" types at present used in this country.

Corrosion Resisting Materials—Non-Ferrous.

The main application of corrosion resisting non-ferrous metals is in condenser tubes. An important advance was made when the

British Non-Ferrous Metals Research Association found that the addition of 2% aluminium to a brass of 76% copper and 22% zinc gave marked improvement in resistance. These alloys are marketed under such trade names as "Alumbro" and "Yorcalbro."

Another well-known alloy for condenser tubes is "Barronia," which has an approximate composition of copper 83%, tin 4%, zinc 12.5%, lead 0.5%. Another alloy, "Tungum," with an approximate composition of copper 82.5%, zinc 14.5%, aluminium 1%, nickel 0.75%, silicon 0.75%, iron 0.25%, gives an ultimate tensile strength of about 20 tons per sq. in. and is claimed to be particularly suited to withstand corrosion resistance.

(4) Light Alloys.

Aluminium and magnesium form the basis of the light alloys, and of these, aluminium has the more extensive application. The best known wrought alloy of aluminium is "Duralumin" containing copper, magnesium, silicon, and manganese up to a total of 7%, and capable of developing a tensile strength of 30 tons per sq. in. if quenched in water from 470°C. and allowed to age for several days.

Other wrought alloys of aluminium which possess good corrosion resistance properties are "Birma-bright" and "MG7." The Rolls-Royce alloy "Hiduminium RR56" gives, after heat treatment, a tensile strength of 30 tons per sq. in. with a relatively high proof stress. The additional elements in this series of alloys are silicon, magnesium, nickel, titanium, and iron.

With reference to cast aluminium alloys, it has been found that the aluminium silicon alloys containing up to about 13% silicon, can, when treated in the molten condition so as to produce, when cast, a finely crystalline metal having good physical properties, produce good castings. Alloys of this type are marketed under such trade names as "Wilmil," "Alpax," "M.V.". "C," etc.

Where castings having greater hardness or strength are required, more complex alloys, the physical properties of which can be altered by heat treatment, are used. Probably the best known is the "Y" alloy developed at the National Physical Laboratory during the war. This contains magnesium, copper, and nickel up to about 7.5%, and its tensile strength can be increased by heat treatment from 12 tons per sq. in. to about 20 tons per sq. in. in small castings.

Magnesium with a specific gravity of 1.75 is only two-thirds the weight of aluminium, but difficulties in manufacture and its poor resistance to corrosion and oxidisation, are against its more complete development. Magnesium alloyed with a few per cent. of aluminium as in "Dowmetal," or with aluminium, zinc, and manganese as in "Elektron" alloys, are the most generally known alloys.

Owing to the ease with which magnesium and its alloys oxidise,

special technique is necessary in casting it. The surface of the moulds should be dusted with powdered sulphur. In machining, precautions must be taken against the spontaneous ignition of fine machine swarf. To protect the alloys against corrosion it is usual to paint or varnish them, special care being taken to degrease the surface before treatment.

(5) Die Castings.

Advances in die castings have been mainly along the lines of improved machines for pressure die casting, and the development of zinc base alloys with aluminium and copper, care being taken to ensure that the zinc used is of 99.9% purity, which gives greater corrosion resistance and permanence of dimensions. Suitable alloys for die castings are marketed under the trade names of " Mazak " and " Zamak." These have exceedingly good all-round properties as regards strength, corrosion resistance, ability to take a fine and accurate impression coupled with moderate cost.

(6) Magnetic Materials.

(The lecturer outlined the historical development of magnetic materials particularly stressing the great economical advantages that accrued from the employment of silicon sheet steels first introduced by Barratt and Hadfield in 1906.)

Perhaps the most striking development of recent years has been the production of nickel iron alloys; " Permalloy " 78% nickel, 22% iron, has a maximum permeability of 100,000. " Mumetal " having 77% nickel, 16.5% iron, 5% copper, and 1.5% chromium, has a permeability as high as " Permalloy " but without its strain effect.

In permanent magnets it has been found that the introduction of 6% tungsten and 3% chromium gives results 15 times as good as carbon steels, and Honda-cobalt steels with from 9% to 35% cobalt, give even better properties, while the recently-introduced " Mishima " aluminium-nickel steels are vastly superior to anything previously achieved.

(7) Electric Conducting Materials.

As regards electric conducting materials, copper still holds first place for general use, with aluminium as a rival for certain purposes. The conductivity of copper is very dependent on purity so that all copper for electrical purposes is produced electrolytically. Some time ago it was claimed that a single crystal of copper gave improved conducting characteristics, but this claim has never been substantiated and conductivity still remains dependent on purity. For certain uses where the space occupied is not of importance, and weight reduction is a primary consideration, aluminium has been employed.

(The lecturer indicated the variety of resistance materials in use, stressing the importance of nickel chromium alloys for high temperature work. The various conducting materials—copper, silver, platinum, tungsten, and molybdenum—were dealt with in relation to their individual applications).

(8) Insulating Materials.

On the quality of its insulation depends the whole safety of electrical plant and, with the increasing size of units and the inter-connection of large electrical systems in which a single failure may result in vast contingent liabilities the importance of this group of materials cannot be over-estimated. The physical conditions which insulation, which may be organic or inorganic in character, has to meet, may include temperatures at which the materials are liable to disintegrate, dampness, chemical fumes, vibration, and mechanical stresses.

Materials in any of the three states of matter—gases, liquid, solid—may be used as insulating materials. The reason why gases insulate can be explained satisfactorily, but at present the theories underlying the insulating properties of liquids and solids are not capable of explanation.

(The lecturer then outlined the properties of the various classes of solid insulation including asbestos, bitumens and waxes, earths, mica, mineral oil, organic fibres, resins, rubber, vegetable oils, etc., and dealt with some of the troubles as, for example, sludging and inflammability in connection with the use of mineral oils).

(9) Synthetic Resins and Plastics.

In recent years a new range of materials, generally known as plastics, has come into being and introduced completely new industries. They originated in the discovery of Baekeland that resins could be produced synthetically. To-day, there are many types of synthetic resin, but they fall generally under three classes : Thermo-plastic, theremo-setting, or they form an insoluble mass in combination with oxygen. They are prepared by two general methods, either by the aggregation of a number of molecules of the same kind, by the process known as polymerisation, or by the interaction of two molecules of a different kind by the process known as condensation.

The principal types of synthetic resins are those produced from phenol and formaldehyde and known as bakelite ; urea with formaldehyde, glypthal resins produced from coal tar and glycerine, cumarone produced from coal tar, vinyl from acetylene and acetic acid, and resin " M " from acetone.

(The method of production, properties, trade names, principal uses of each class were described).

(10) Miscellaneous Materials.

There are an immense number of materials of a miscellaneous kind employed in one or other of the branches of engineering, but it is proposed to mention only three.

(*a*) *Light sensitive*. Certain materials such as Selenium, possess the property of having their electrical resistance altered when exposed to light. This property is employed in certain light-detecting apparatus and may play a very important part in television development. Already the Selenium cell is finding extensive application as, for example, in the measurement of light intensity, for opening and closing doors, for operating signals, etc.

(*b*) *Rectifying*. Certain films like copper oxide, have the property of rectifying alternating to direct current, and have important application in the production of rectifiers. Similarly, certain vapours, notably of mercury, possess this property of rectification.

(*c*) *Soundproof*. The problem of noise and its elimination has received considerable attention in recent years. The problem of eliminating noise has been tackled by analysing, by electrical methods, the dominating notes that are responsible for the noise, and from these determining those vibrating members of the machine or apparatus that are responsible.

For reducing sound transmission through walls or partitions, materials have been developed which combine a large sound attenuation with light weight, two largely antagonistic properties. Numbers of such materials are available and their properties have been scientificially determined. There are, also, many materials for sound absorption, for damping down echo within a room. If such a material is mounted on a wall, the incident sound passing through it is attenuated and it is reflected by the wall, being again attenuated in its passage back through the material.

Processes : (a) Welding.

The term " welding " is generally limited in its application to cast or wrought iron and steels, and may be defined as the joining together by localised fusion of two or more component parts.

(*The history of welding was outlined with particular reference to the work of the Manchester Physicist* " *Joule,*" *who in* 1856 *in his paper* " *Fusion of Metals by Voltaic Electricity,*" *forecasted electric welding in the sentence* " *In many instances the process would advantageously supersede that of soldering.*")

The four main classes with sub-divisions for particular methods of applying welding are as follows :—

Class 1.—Fire Welding.

(*a*) *Blacksmith's Weld*. The parts to be joined are heated in the

blacksmith's hearth until fusion point is just reached. The surfaces are sprinkled with sand to act as a flux and the parts hammered together.

(*b*) *Foundry Burning*. This consists of pouring molten metal on to the defective region surrounded by a suitably shaped sand mould until local fusion occurs and the defective region is built up with new metal.

Class 2.—Electric Welding.

(*a*) *Resistance Welding*. This consists in the localised heating due to the high resistance of the contact surfaces of the parts to be joined, by the passage of a heavy electric current from a special transformer. The joint is completed by pressing the parts together. Variations of this process are known commercially as resistance butt welding, resistance spot welding, and resistance seam welding.

(*b*) *Carbon Arc Welding*. In this method the heat developed by the arc between two carbons, or one carbon and the job, is employed to fuse both the surface and the filling ground, the joint being completed by using the arc to puddle the fuse metal into the smooth joint.

(*c*) *Metallic Arc Welding*. This process is similar to the single electrode carbon arc, except that the metallic filler road replaces the carbon electrode. When the arc is struck drops of molten metal from the end of the rod are deposited to the surface of the job. Development of his process, which is by far the most popular, has largely been concerned with improvements to the welding electrode.

(*d*) *Percussion Welding*. The main difference between this and resisting welding is that the welding current is obtained by the discharge from a condenser, and not from a transformer.

(*e*) *Atomic Hydrogen Welding*. In this process the arc is struck between two tungsten wire electrodes and its heat used to dissociate a stream of molecular hydrogen blown across the arc in the direction of the job. The resulting hydrogen re-combines a little way beyond the arc to form molecular hydrogen with the evolution of considerable heat. The region of this re-combination is employed as the source of welding heat which is used to fuse the filling wire into the joint space provided.

Class (3)—Gas Welding.

(*a*) *Oxy-Acetylene welding*. Oxy-acetylene gas welding generally implies oxy-acetylene welding, although oxy-hydrogen and oxy-thermalene processes are sometimes employed. The oxy-acetylene process is carried out by means of a special torch feeding oxygen and acetylene by separate pipes to a common jet where combustion takes place. The heat of combustion causes fusion of the surfaces to be joined and of the filler rod.

Class (4)—Chemical Re-action Welding.

In this class the only process having extensive use is the Thermit process which depends for its action on the heat developed during the chemical re-action between finely divided aluminium and magnetic iron oxide.

(B)—Surface Treatment.

Surface treatment is generally applied for three purposes: To produce a hardened surface, for protection against corrosion and scaling, and for finish. The following are the methods of surface treatment generally in use.

(*a*) *Sheradising*. Several surface treatment processes depend upon the diffusion of one metal into another, thereby forming surface alloys which have greater resistance to attack than the base metal. In carrying out these processes the part is packed in a powder, usually a mixture of the metal to be applied and its oxide, and heated to a suitable temperature at which diffusion of the metal into the part takes place.

The penetration is usually not large, but sufficient for the service required. In sheradising, steel is treated with a surface of zinc.

(*b*) *Calorising*. This is the process applied to steel parts to increase their resistance to oxidisation and scaling by furnace gas at high temperature. In this, aluminium is caused to diffuse into a surface of steel. The treatment is carried out at from 875° to 900°C., in a hydrogen atmosphere, to prevent premature oxidisation of the aluminium.

(*c*) *Hot Dipping*. Hot dipping processes, such as galvanising and tinning, are well known and fairly old. In processes of this type a bath of the molten metal is covered with a layer of molten flux, through which the part to be dipped is passed and so is suitably pickled in order to take a continuous coating of the metal.

(*d*) *Metal Spraying*. In the original "Schoop" method of metal spraying the metal to be sprayed is in the form of a wire which is fed into an oxy-hydrogen flame where it melts and is carried forward by the flame, as a spray, on to the surface to be treated which has previously been sand-blasted. The first metal sprayed interlocks with the irregularities produced by sand-blasting and the coating is built up to the desired thickness.

Although various metals are used in spraying, zinc is the chief.

(*e*) *Coslettising*. In process of this type a coating consisting essentially of phosphate of iron, is produced on the articles treated, giving a black finish. Essentially the process consists of submitting the surface to attack by phosphoric acid.

(*f*) *Parkerising*. This is a modification of Coslettising by adding manganese dioxide to the bath, producing thereby, it is claimed, a superior coating.

(*g*) *Oxide Coating*. A very old process of oxide coating to give protection against corrosion, is to submit steel to a highly superheated steam whereby the blue magnetic oxide is produced as, for example, on gun barrels. This process has had many modifications and it has now been superseded on account of the length of time required, by bath treatments, notably molten oxiding salts such as potassium nitrate.

(*h*) *Electrolytic Coatings*. Attempts have been made to produce oxide coatings electrolytically and the most important and successful has been the production of aluminium oxide on aluminium, and certain of its alloys. The article to be treated is made the anode in a bath, usually of Chromic acid. This process has become known as the anodic treatment.

(*i*) *Surface Hardening by Diffusion*. Case hardening of steel parts by surface carburisation is an old and well established process. In the early days it was applied mainly to wrought iron parts in order to combine the toughness of the core of wrought iron with the hardened case. It is now common to case harden a very wide variety of steels, including carbon steels up to 4% carbon, nickel steels up to 5% nickel, and chromium molybdenum steels. Improvements in the process, which is too well known to repeat here, have taken the form of the use of special carburising media, to save time and in the better control of the process to obtain deep cases, as is required, for example, in large heavy duty gears and roller bearings.

For a light case on small parts, a cyanide bath, consisting of molten soldium cyanide and sodium carbonate is most suitable. The bath is usually run at 850° to 900°C. for about two hours to produce a case of about .02 in. thick. Apart from the cyanide bath, carburising is done by a carbonaceous powder as a medium, generally a mixture of wood and animal charcoal with barium carbonate. With this method extra heavy cases can be obtained by raising the temperature up to 1000°C., and increasing the time to two or three days.

(*j*) *Nitriding*. The most notable development in recent years of surface hardening is the use of nitrogen in place of carbon. The hardness of a carbon steel is due to its iron carbide. It has long been known that nitrogen diffused into steel at elevated temperatures formed iron nitride which upon a polished and etched section appeared as needles under a microscope. Steel with nitride needles, however, was brittle and generally unsatisfactory. Dr. Fry of Krupps discovered that if certain steels were submitted to an atmosphere of ammonia at 500°C., dissociation of the ammonia occurred at the steel surfaces and nitrogen diffused into the steel, forming the finely divided nitride or iron, and a layer of great hardness. The layer, however, is of limited depth, about $^1/_{32}$ in. This process of nitriding certain steels, although it suffers from the limitation of small depth of case, possesses the important advantage over car-

burising that on account of the low temperature treatment and the absence of a quenching operation, there is practically no distortion. Consequently, the process is specially applicable to parts of high precision, such as accurate gears where loading is not heavy. The process is finding application to many parts, for example, gear wheels, pinions, and worms, gauges, and small machine parts requiring a hard surface.

The first steels used for nitride hardening were nickel chromium steels containing about 1% of aluminium. At first it was thought that aluminium was an essential element. Although the hardest case is obtained with a steel containing aluminium it is known now that many aluminium-free steels will nitride, notably steels containing molybdenum, such as chromium-molybdenum steels, and they are being used for the purpose because of their greater toughness than the original nickel-chromium-aluminium steel.

The nitride hardening process is being run by a group of steel firms in this country under the name of "Nitralloy."

(*k*) *Surface Hardening* (*by quenching*). Sumpter of Vickers patented the process of locally heating the surface of steel by means of an oxy-acetylene flame and quenching the heated area immediately by a water jet. The water jet followed immediately behind the torch. The part to be treated is usually almost submerged in a water bath leaving exposed the area to be treated. For example in the case of gear wheels and pinions the wheel or pinion is rotated about a horizontal axle and the tooth to be heated is at about the end of the horizontal diameter and just above the surface of the water. When treated the tooth is just submerged bring the following tooth into position for treatment.

The treatment has been applied extensively to gears such as are required for tramway motors. It has the advantage of producing but little distortion, and therefore no correction afterwards by grinding is necessary to produce a smooth-running gear.

(*l*) *Micronising*. For many purposes, materials in a finely-divided state are desirable. A notable example, for instance, is in the manufacture of carbons for arc lamps, commutator brushes, and for lead pencils; another is powder used as cosmetics. Various methods of producing such materials have been employed since the beginning of time, but the most recent method is that known as micronising, in which the materials to be reduced in size are rubbed together by a rotary motion in a chamber, into which is admitted, through nozzles, air or steam at considerable pressure. The mutual friction between particles gradually reduces their size to almost any desired amount, and in this way it is possible to divide finely almost all materials that have any practical application in such a state.

This process known as micronising seems likely to open up possibilities, not only of more economic grinding of special materials, but also to provide outlets for materials which in a finely-divided state possess properties hitherto unsuspected as far as as their commercial application is concerned.

(*m*) *Aluminising*. Recent developments in high vacuum apparatus and technique have enabled new methods to be evolved for the production of metal films on glass and other materials. The principles involved are simple. A suitable vessel is evacuated to pressures of the order of 10—5 mm. of mercury and the metal to be deposited is boiled from a heater system in the vessel on to the surface to be coated. The practical essentials are the maintenance of the low pressure, cleanliness of the parent surface, and, for commercial work, high pumping speeds and easily dismountable equipment. Interesting properties are possessed by films produced in this way ; for example, aluminium is found to have about the same reflectivity as silver in the visible region of the sectrum and to be some 10 or more times better in the ultra-violet. The obvious application to astronomical, scientific instrument, and other mirrors has received considerable attention, while there is every expectation that films of other metals will be used as the reflecting surfaces of decorative mirrors. In the case of aluminium its non-tarnishing properties make it very suitable for any application in which a surface mirror is required as distinct from a backed mirror.

(*n*) *Electrolytic*. Electro-plating in its widest sense commenced as an art nearly 100 years ago. Copper and silver were the first metals deposited by means of the passage of an electric current through a solution containing a salt of the metal to be plated. The principles underlying the art of those early days govern the scientifically controlled processes of to-day. The groups into which electro-deposition may be sub-divided are : (1) Electro-refining ; (2) electro-forming ; (3) electro-deposition ; (4) Protective coatings.

(1) *Electro-refining*. The difference between this and the other processes is that a large number of cells are connected in series so that standard line voltages can be utilised, whereas the others are usually operated as individual units taking their current from low voltage generators. Electro-refining has grown into an enormous industry producing, in the case of copper, about 1,000,000 tons annually. Other metals that are refined electrolytically are zinc nickel, aluminium, magnesium, calcium, and alkali metals.

(2) *Electro-forming*. This is the art of reproducing a mirror image of an article by means of electro-deposition, or reproducing it by means of plating on to a plaster-cast.

(3) *Electro-deposition*. This term has taken on a specialised meaning and relates to the production of thick deposits for wear-resisting purposes or for the building up to size of worn out or undersized

parts. Care must be taken that the adhesion of the deposit to the basis metal is perfect, because of the subsequent work to be carried out on the article.

(4) *Protective Coating.* Metals commonly deposited are copper, zinc, lead, chromium, tin, cadmium, silver, gold, platinum, palladium, rhodium, brass, bronze, iron, and cobalt, but many of these are used for decorative rather than for truly protective purposes.

(C)—Heat Treatment.

Heat treatment of steel is an old established art which has become a science as a result of the tremendous advance in the knowledge of metallurgy that has been made during the past fifty years. The essentials of heat treatment have remained substantially the same as have been employed by the blacksmith in dealing with a chisel, which would be heated to a red heat judged by the eye, the end quenched or cooled in water and removed ; the heat in the uncooled part of the chisel being allowed to re-heat the end until the temperature attained, as indicated by the oxide or temper colours, was suitable for the service required, when the whole chisel would be cooled off in water. If it were required to soften the chisel it would be cooled off in air from its original red heat, or in ashes were it required to be particularly soft. In this example, there are all the essential processes of heat treatment, i.e., hardening, tempering, normalising, and annealing.

Modern heat treatment has consisted in introducing refinement and control in carrying out these processes. Electric furnaces, time limit switches, temperature operated switches, and recording pyrometer, etc., all assist in this refinement and control.

For mass production work furnaces are designed and built for single types of pieces and incorporate rotary hearths, conveyer mechanisms, and push-bars and other devices.

The heat treatment of very large forgings and castings required in modern engineering development is not as simple as the heat treatment of small parts, though the job is the same. With large pieces of steel there is a risk that during heating and cooling the temperature gradients through the parts may produce sufficiently high initial stresses as to cause cracking or failure in service. For this reason the final treatment needs to be properly regulated and with the largest parts this means cooling slowly in the furnace from a temperature high enough to ensure absence of stress at the commencement of cooling—about 600°C.

Measurement.

Measurement is the basis of all scientific progress and an important factor in the progressive development of new materials and processes. There are an infinite variety of measuring instruments which arise

from a few well-established principles. It is noteworthy that in the increasing need for the measurement of infinitely small entities such as minute periods of time, minute forces, minute displacements, minute amounts of energy, electrical methods are predominant.

By way of illustration of a few modern method of measurement the following will be described :—

Coker apparatus.
Cathode Ray Oscillograph.
Sulphur prints for metallurgical work.
Magnetic crack detection.
X-rays.

Theories of Matter.

It is not my purpose to delve into the various theories of matter or to indicate the possible reasons why many materials should theoretically have very much better physical properties than they present in practice, but rather to call attention to the fact that in increasing the boundaries of knowledge, all workers—whether the scientist in the laboratory or the foundryman or machinist—are in their own spheres acquiring new knowledge. In earlier days it was thought that the smallest indivisible entity of matter was the atom, and that groups of atoms combined to form molecules. To-day we appreciate that the atom has a structure of its own, comprising a nucleus around which rotates one or more negative electrical charges known as electrons. Further research reveals the nucleus itself to be a complicated structure and there appears to be no end to the discovery of sub-atomic entities, such as the neutron, deutron, and positron, each one having its own particular characteristics.

A time-lag exists always between the discovery of new fundamental knowledge and its practical application. Faraday's fundamental discoveries 100 years ago took half a century to come to commercial development. J. J. Thomson's discovery of the electron, which is substantially the basis of all modern radio work, took ten or twelve years to bear fruit. The work of the pure scientist to-day may well take practical form in a few years' time. It is important to the scientist on the one hand and the so-called practical man on the other, each to appreciate the other's sphere of activity. In the field of metallurgy, for instance, the scientist in his work sub-atomic physics, is pushing out a cantilever, while the metallurgist, whose work is of a more practical character, is pushing out from his side of the gap, and with the meeting of the two we shall get a vast step forward in the scientist control of the production of materials which will yield the maximum physical properties. To-day, we are largely dependent on what chance offers.

Discussion.

MR. T. FRASER : In listening to this lecture one realises how one is apt to take for granted the various new materials that have been spoken about ; and it is not until we get someone like Mr. Fleming to come along that we realise the amount of effort and research that is put into it. Mr. Fleming has covered such a wide field that it is going to be extremely difficult to ask a question at all ! There is, however, one point on the welding of stainless steel—I never realised before the amount of trouble there was in welding steel, and I would like to ask if there is any particular form of electrode in welding used for stainless steel ?

MR. FLEMING : For welding the usual stainless steel containing 12 to 14% chromium there are special metallic arc electrodes made which deposit a steel of approximately the same chromium content. Covered electrodes are used and usually the composition of the covering contributes chromium to the deposit. One difficulty in welding stainless steel of the 12 to 14% chromium type is that the heating and cooling during welding produces hardening, and welds should be heat treated to produce satisfactory physical properties. Rustless iron, which has a lower carbon content (of the order of 0.06 to 0.1%) is free from this hardening property and therefore should be used instead of stainless steel wherever it may be possible. In the case of the 18% chromium, 8% nickel or Staybrite type of steel, covered electrodes are also used, but for thin sheet, say ⅛ in. and less, atomic hydrogen welding is very satisfactory. The outstanding defect of stainless steels of the Staybrite type has been the effect of the temperature at the region of the boundary of the weld, bringing about a condition which makes the material liable to intercrystalline cracking under certain corrosion conditions. The phenomenon has been investigated and overcome by the addition of titanium and/or silicon to the steel. These steels are therefore reasonably free from this weld defect, termed " weld decay," and should be used where welding is to be done.

MR. CROOKE : With regard to the Staybrite type of steel, I wonder whether the lecturer can give me any information regarding rustless steel with a good machinability. I have seen samples in this lecture room where there has been a machining operation—threads, splines, etc., but when one wants to work on that type of steel, one runs up against all sorts of difficulties, such as tearing of the metal, and all that sort of thing.

With regard to tungum, we have one particular component where we usually obtain a material having a fair amount of wearing

quality which is quite good from a non-corrosion point of view. The part is at present made from a good quality free-cutting steel. That free-cutting steel does machine wonderfully, but when it gets into some climates, then we have this corrosion trouble. In endeavouring to alleviate that we tried to get another material. Tungum was tried and was quite good, the only trouble being that in getting hardness by rolling there is always a distortion during the machining operation and we got all sorts of shapes that rendered the parts useless. Then we tried stainless steel, but the trouble was in not being able to machine it to get the beautiful finish desired.

MR. FLEMING: That point is especially in regard to machining problems. When I was first asked to give this lecture, I felt that my own limitations in regard to machining experience were such that I would prefer to leave that matter entirely out. What you say is borne out by the general experience of others. It does bring up this one rather important point, and that is, when one gets away from the simple carbon steels, or gets away from the simple non-ferrous alloys, then you always have to face a compromise. You might get one perfectly good characteristic but you have to sacrifice others. It comes to this—when an alloy of two materials is made, prediction of its properties is uncertain and for that reason some quite unexpected results have sometimes been obtained. Difficulties increase considerably with more complex alloys, e.g., with three or four metals, and prediction must be based upon experience guided virtually by rule of thumb methods. Frequently, to obtain one outstanding property others must be sacrificed.

Stainless steels generally are more difficult to machine than the usual steels of construction. Mr. Crooke refers particularly to the Staybrite type which, as he mentions, has a tendency to drag. Steel makers have done something to improve the machinability of this class of steel and have produced steels of somewhat modified composition as, for example, the "D.D.Q." quality of Staybrite steel, manufactured by Firth-Vickers Stainless Steels, Ltd. and containing approximately 13% chromium and 13% nickel. A steel of this kind possesses definitely better cold working and machining properties to the 18 : 8 variety with almost as good corrosion resistance. The guiding principles when machining austenitic steels are to employ low speeds and fairly heavy cuts, using tools having a keen edge. It is important to avoid rubbing of the tool on the job, drills, for instance, being fed straight into the job and kept cutting steadily. Lubrication with a machining oil containing colloidal graphite shows promise of increasing tool life and cutting speed.

With regard to the distortion of cold-worked brasses and bronzes on machining, our experience confirms that manufacturers do sometimes rely too much on cold-work to obtain high strength and

elasticity. We have, on several occasions, found non-ferrous drawn sections to contain such high internal stresses that it was in an unstable condition and liable to fail by "season-cracking," i.e., spontaneous cracking in service or during storage. There is no excuse for this condition since the trouble should by now be fully understood by manufacturers. The danger of season-cracking can usually be prevented by low temperature annealing (250° to 300°C.) which reduces the hardness very little and the dangerous condition can easily be detected by the mercurous nitrate test, i.e., immersing a clean sample of the bar or tube in a 3% solution of mercurous nitrate ($HgNO_c$) for half an hour.

MR. F. W. SHAW: My interest lies in production machinery. I have been faced with the problem of getting two cubic feet of material into one cubic feet of space for the sake of compactness. To do this, naturally it means that many of the elements must be cut, not nearly to the bone, but right into the bone. It is not mere tensile strength that counts, but the ability of the material to resist deflection. In fact, after you have designed round the deflection you can very often ignore calculations altogether of strength. Now in the days when mild steel formed the major portion of the stress elements, calculation did not play the very great part in design it does to-day, but failures from deflection were quite common. You know what happens with a machine too when you get over-deflection —you get vibration, which not only tends to reduce the output but has a very vast influence on the life of the tools. Our lecturer has not said much, if anything at all, about the modulus of elasticity of materials. He has mentioned tensile strength, but no modulus of elasticity, upon which the ability to resist deflection depends. You can design a thing which is quite strong and will not deflect beyond the elastic limit. What I want to know is this—a lot of time and study and investigation have been devoted to the question of increasing the strength of materials, but how much time has been devoted to endeavouring to increase the modulus of your elasticity to reduce deflection? That is an important thing. Is it possible by any means whatever to increase the modulus of elasticity of given materials with the exception of certain things. We know, for instance, that wrought iron in an unannealed state has higher modulus of elasticity than in the annealed state. A fair amount higher, but when we come to the steel, and the materials upon which we rely for the real stress bearing members, we find that the modulus of elasticity varies between 25 mm. and 30 mm. Cannot the physicists help us in this direction? What is the cause? How is elasticity to be explained? What is the cause of elasticity of the material? If we got down to the root cause of elasticity, is it possible that by some means we could discover whether to increase it and so enable us to design our machines on much more compact lines than

at the present moment ? Suppose you could make the modulus of elasticity ten times greater ? Look what you could save in materials where mere mass does not count in resisting vibration.

Mr. Fleming : The point you raise bears rather curiously on the fact that in trying to arrive at what I could cut out, or rather what I should put in to the paper, I had drawn up a very comprehensive chart showing modulus for the group materials, but in discussing the matter with one of my colleagues who had given a good deal of attention to the point you are discussing, I discarded this for the reason that for a given class of alloy the modulus of elasticity is subject to only comparatively small variation and so far there appears to be small prospect of changing the position. You ask what the physicists are doing in the case of various materials that are subject to high temperatures and high stresses for the most difficult conditions we have to meet in steam practice. It is quite possible to meet severe operating conditions by increasing the strength of the material, but when it comes to its behaviour as regards deformation in service, then I think the problem does depend on maintaining cohesion at the grain boundaries. Now, while it is possible by alloying various materials to increase resistance to deformation or increase strength, there does not yet appear to be a way to increase the cohesion at the boundary. A great deal of research is being carried out in that field. When we consider what is being done to improve materials for use at those very high pressures and temperature at which it is hoped certain engineering plant will operate in the near future, I imagine the solution of the problem may point the direction in which your particular problem will have to be met.

Mr. Leslie : Will Mr. Fleming tell us whether it has been found possible so far to find a material to substitute the imported fibre for the purposes of electrical insulating where carbonising and tracking take place ? So far we have been dependent on imported fibre to withstand that condition. I know research has been taking place in compressed materials, compressed wood, and so on. Alternatively, is it possible to " face " the surface of boards with better surface resistance to carbon tracking ? I would like a little more explanation on the question of growth of metal. I have in mind the problem confronting mechanical engineers where fine clearances have to be maintained at high temperatures.

Mr. Fleming : One of the weaknesses of the bakelite type of materials is admittedly their tendency to track when exposed to arcing conditions. This weakness is inherent in resinous products of the phenol formaldehyde type. There are, however, on the market other synthetic resins which do not exhibit tracking properties. These include a product known as Panilax, the manufacture of which has recently been commenced in Great Britain. Experimental

investigation has clearly shown that of the fibrous insulating materials vulcanised fibre is by far the best material for use where tracking is anticipated, as for instance in fuse holders, etc. It must be borne in mind, however, that vulcanised fibre is highly hygroscopic and is not itself a very high grade insultation.

In order to obviate the necessity of having to use large quantities of imported fibre it is possible to follow a practice which has already been adopted in certain countries where it is important to keep down imports. This practice consists of facing the inner walls of the fuse tubes and other parts where the surface is exposed to the arc with imported fibre and using Bakelite-varnish materials for giving the main mechanical support. Fuse tubes made in this way are now available. Where it is possible to utilise inorganic materials Mycalex may be mentioned as material which possesses particularly good arc resisting properties and which also can be machined and worked if it is raised to a suitable temperature.

In regard to growth of materials, apart from the ordinary condition of temperature expansion, there is a phenomenon of actual growth in the case of cast iron, both at really high temperatures and also in the presence of steam at medium and high temperatures. Growth in this case is definitely one of oxidisation by the penetration of oxygen and/or steam in the comparatively porous structure of the material. Creep, which is the phenomenon I think is involved by your question is the progressive permanent deformation of a material under stress. This occurs at high temperatures and in the case of steel under a particular stress is greatly reduced at high steam temperatures by the addition of 0.5% molybdenum. The addition of chromium, tungsten, and vanadium is also useful. At present steels with 0.5% molybdenum or 1.5% molybdenum and 1.0% chromium are commonly used to minimise creep at operating temperatures of 400° to 500°C., or 750° to 932°F.

A vote of thanks to Mr. Fleming concluded the proceedings.

Appendix: Particulars of Lantern Slides shown by Mr. Fleming.

I.—Materials.

HARD METALS FOR CUTTING TOOLS.

Trade Names.

General Composition :—

(*a*) Tungsten Carbide—cobalt or nickel binder.
(*b*) Tungsten and Titanium Carbide—cobalt or nickel binder.
(*c*) Tungsten and Tantalum Carbide—with nickel binder.

Methods of Manufacture :—

Pressing, heating, shaping, and sintering (1400° to 1500°C.).

Applications :—

(*a*) Cast iron. (*b*) Steel.

Alloyed Steel Tools :—

Cobalt, tungsten, chromium, molybdenum, vanadium.

STEELS FOR HIGH TEMPERATURES AND PRESSURES.

Temperatures 450° to 550°C. Moly. up to 0.1%. Forgings, etc., 5% Moly Steam Turbines and Boilers .5% Moly. and 1% Chromium. Importance of Tempering Conditions. Grain Deformation and Grain Boundary Adhesion The Effect of Hydrogen on Alloys .5% Moly., 6% Chromium.

CORROSION-RESISTING—FERROUS.

Stainless : Brearley—Cr. 12 to 14% ; Krupp V2A—Cr. 18%, Ni .8%—Austenitic. Staybrite, Anka (British equivalents).

Rustless : Cr. 12 to 14% Cutlery—C. 0.3 ; Turbine blading—C. 0.25 Forgings—C. 0.15—0.20 ; Rustless Iron—C. 0.08—0.12.

18 : 8 Type : Weld Decay. Krupp—1% Ti., 1% W. F.D.P. Brown Bayley—1% Si., 1% W. Weldanka.

CORROSION-RESISTING—NON-FERROUS METALS.

Most important in condenser tubes.

Alumbro (B.N.F.M.R.A.), Yorcalbro : Cu.76, Zn.22, Al.2.

Barronia : Cu.83, Sn.4, Zn.12.5, Pb.0.5.

Tungum : Cu.82.5, Zn.14.5, Al.1.0, Ni.0.75, Si.0.75, Fe.0.25, U.T.S. 20 tons per sq. in. Good corrosive conditions.

HEAT-RESISTING.

Resistance to scaling due to oxide film.

Steel : Al.(12 to 14%) ; Ni.—Cr. (20 to 40%).

LIGHT ALLOYS.

AL. ALLOYS :—

(*a*) Wrought : " Duralumin "—Cu. Mg., Si., Mn. to 7%. U.T.S. 30 tons per sq. in.when quenched from 470°C. and aged. " Birmabright " and " MG7 " (resistant to sea water.) Hiduminium RR56—Si., Mn., Ti., Fe., Ni. U.T.S. 30 tons per sq. in. after heat treatment.

(*b*) Cast : Wilmil, Alpax, Silumin, M-V. " C "—Si. up to 13%. " Y " Alloy—Cu., Ni., Mg. up to 7.5%. U.T.S. 12 tons per sq. in. before heat treatment ; U.T.S. 20 tons per sq. in. after heat treatment.

MAGNESIUM ALLOYS :—

Alloyed with Al. " Dowmetal." Alloyed with Al., Zn. and Mn.— " Elektron " Alloys.

Technique to prevent oxidation : Moulds dusted with sulphur powder ; painting of surface after degreasing and immersion in oxidizing reagent.

DIE CASTINGS.

ADVANCES : Improved machines for pressure die-casting. Development of zinc base alloys with Al. and Cu. Zn. used should be 99.9% pure. " Zamak " and " Mazak "—Strong, corrosion-resisting, fine and accurate impression, moderate cost.

MAGNETIC MATERIALS.

HISTORICAL DEVELOPMENT : Laminated Sheet—Swedish Soft Iron, Mild Steel, Ageing, Rolling and Annealing, Permalloy, Mumetal, Hypernik, Permanent Magnets.

ELECTRICAL CONDUCTING MATERIALS.

Copper—Aluminium.

Resistance Materials—Copper-Nickel, 60/40 ; Copper-Nickel-Zinc ; Copper Nickel-Manganese.

Resistance Materials for High Temperatures—Nickel-Chromium, 1100°C. ; Nickel-Chromium Iron, 800°C.

Contact Materials—Copper, Silver, Platinum, Tungsten, Molybdenum.

INSULATING MATERIALS.

Importance. Forms : Gases ; Liquids ; Solids. Physical Properties Future Developments.

Asbestos, Bitumens and Waxes, Earths, Mica, Mineral Oils, Organic Fibres. Resins, Rubber, Vegetable Oils, Wood-Solvents.

SYNTHETIC RESINS.

GENERAL CLASSIFICATION :—

Thermo-Plastic ; Thermo-Setting ; Combination of Resin and Oxygen into Insoluble Mass.

PRODUCTION :—

By Polymerisation—aggregation of similar molecules. By Condensation—interaction of different molecules.

TYPES OF SYNTHETIC RESIN :—

Bakelite—Phenol-formaldehyde ; Urea—Formaldehyde ; Glyptal—Coal tar—Glycerine ; Cumarone—Coal tar ; Vinyl—Acetylene—Acetic acid ; Resin M—Acetone.

PLASTICS.

USES :—

Electrical—Mouldings, laminated materials ; Non-electrical—decorative boards.

THERMO-HARDENING :—

Fabrolite (B.T.H.), Bakelite, Mouldrite, Elo (Birkbys).

THERMO-PLASTIC :—

Kalinite (Callenders), Scarab (Beetle Products), Diakon (I.C.I.), Troliut (German), Mycalex (High Temperature Work).

MISCELLANEOUS.

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SPECIAL MATERIALS.

Nitralloy Steel—Chromium-Aluminium—Tempered and Treated in N. Tungum—High-Grade Bronze, Cu. 82.5, Zn. 14.5, Al. 1.0, Si. 0.75, Ni. 0.75, Fe. 0.25. Elektron—Magnesium with 10 to 15% Aluminium. Meehanite Cast Iron—Change in structure of graphite by addition of calcium or calcium silicide. Special Aluminium White Metal.

II.—Processes.

WELDING.

HISTORICAL.

PROCESSES :—

(1) Fire welding—Up to 1900. (*a*) Blacksmith weld ; (*b*) Foundry burning.

(2) Electric welding—1856 Joule. (*a*) Resistance, 1877 (butt, spot, seam) ; (*b*) Carbon arc, 1885 ; (*c*) Metallic arc, 1900 (slag, coat, electrode alloy) ; (*d*) Percussion ; (*e*) Atomic hydrogen.

(3) Gas welding—Oxy-acetylene, 1895.

(4) Chemical reaction—Thermit, 1898 (Al. and magnetic iron oxide).

SURFACE TREATMENT.

(1) SHERARDISING—Diffusion of metals forming surface alloy with zinc—400°C.

(2) CALORISING—Diffusion with Al. oxide—900°C.

(3) HOT DIPPING.

(4) METAL SPRAYING—Schoop Gun.

(5) COSLETTISING—Surface treated with phosphoric acid at 80°C.

(6) PARKERISING—Manganese dioxide and phosphoric acid.

(7) OXIDE COATINGS : (*a*) Superheated steam ; (*b*) Potassium nitrate.

(8) ELECTROLYTIC COATINGS : Anodic treatment ; Al. oxide on Al. Treatment of Al. oxide with dyes.

(9) SURFACE HARDENING BY DIFFUSION : Case hardening by surface carburisation using carbonaceous medium at 800° to 1000°C., and quenching. Case hardening of small parts in molten sodium cyanide and carbonate 850°C. to 900°C.

(10) NITRIDING : Surface hardening by N. in place of C. ; Ammonia at 500°C. applied ; Nitralloy.

(11) SURFACE HARDENING BY QUENCHING : Oxy-acetylene flame heating and water jet.

(12) SPUTTERING.

(13) ALUMINISING.

(14) ELECTROLYTIC : Refining—Cu., Zn., Ni ; Forming—Medallions—records; Deposition—Building up ; Protection, etc.—Cu., Ni., Cr., Sn., Cd., Au., Ag., Pd., Rh., Fe., Co., Pb.

HEAT TREATMENT.

Heating, quenching, tempering (colour). Modern method—molten salt bath—electric furnace, temperature control. Heacy forgings—temperature gradient, initial stress.

MICRONISING.

DENSIFICATION.

III—Measurement.

Examples : Coker Apparatus ; Cathode Ray Oscillograph ; Schering Bridge Sulphur Prints ; Magnetic Crack Detection ; X-Rays.

IV—Theories of Matter.

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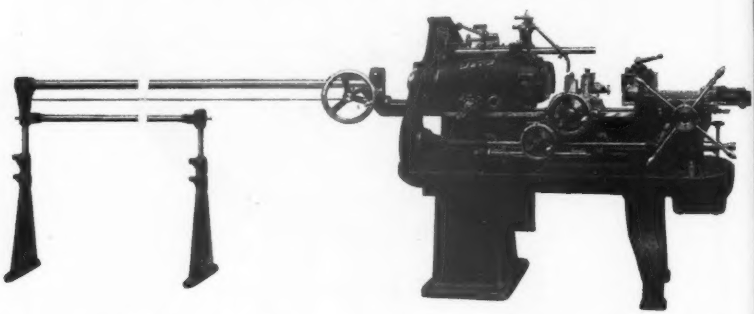

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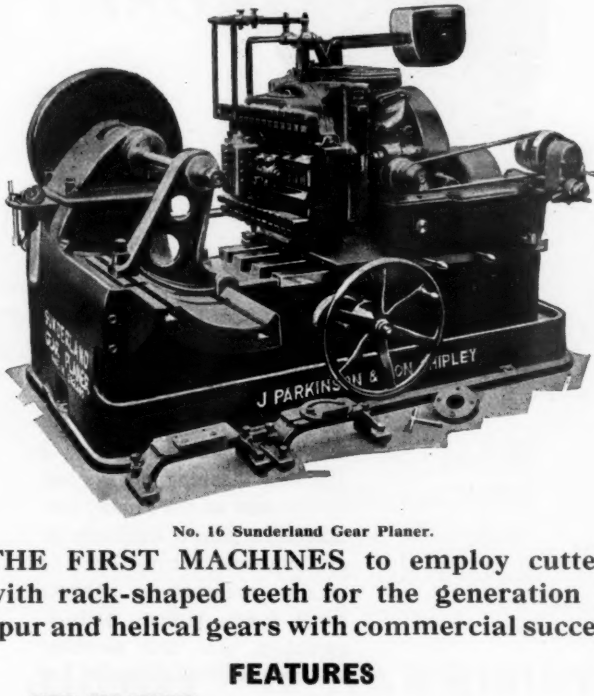

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